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FOREWORD

Following the recent publication of the results from soil research carried out by Dr. Keen and others at Rothamsted and elsewhere, some of which conflict with previously accepted theories, agriculturists in Britain have been asking themselves whether their methods of husbandry are in need of overhauling. The same question may well be asked by agriculturists in East Africa after reading Dr. Martin's outstanding article in this number in which he gives some of the more important results obtained from soil research carried out in Uganda during the past ten years.

One of the most urgent problems facing us in East Africa for years past has been the maintenance of soil fertility, a problem which for various reasons cannot usually be solved as it can in Europe by the adoption of a system of mixed farming combined with the application of farmyard manure and the rotation of crops. Instead, we in the tropics pinned our faith for some years on rotational green manuring, a system which failed to produce the results hoped for in the beginning. Dr. Martin has now opened a new and exceedingly hopeful approach to the problem by showing the all-important part played by soil structure in maintaining fertility (providing better subterranean pasturage for the plant and better penetration of rainfall). The basis of these successful Uganda experiments has been the adoption of a grass rotation, a system which holds out great possibilities since it is one which can be followed by native farmers without making violent changes in their traditional methods of farming. A valuable feature of Dr. Martin's article, which will be duly appreciated by readers, is his final note on the practical application of his work, an aspect of research which, unfortunately, is sometimes omitted by even the best scientists when describing their work.

The perusal of the recent publication "Agricultural Research in Great Britain" (Cmd. 6421) gives one the impression that in Britain, unlike East Africa, a very considerable amount of agricultural research is still being carried out by the various research organizations, in spite of the problems created by the war. In East Africa, on the other hand, because of our limited resources of man power, one of the almost inevitable results of the war has been the temporary diversion of many scientific workers from agricultural research to other activities which, rightly or wrongly, were considered to be of greater immediate importance during wartime. Thus we have seen the physiologist managing a factory and the geneticist running a farm, the result being the almost complete dislocation of the programme for central agricultural research. It is particularly satisfactory therefore to find that in one respect agricultural investigations on an inter-territorial basis have gone ahead during the war, namely the trials undertaken to produce seeds of temperate vegetables in the tropics, a subject on which, until recently, we knew particularly nothing, as pointed out in two articles published in this Journal earlier in the war. This work is described in this number by Capt. Hawkins, recently appointed Seed Specialist to the Governments of Kenya, Tanganyika and Uganda, who reviews the immediate problem and makes suggestions for the future. His article, which is in the nature of a progress report, shows that a good start has already been made with an investigation which should be of value not only to East Africa but to the tropics in general. The immediate problem is to supply a wartime need, but it is to be hoped that the logical development of the present undertaking, a scheme for the breeding and selection of vegetable varieties specially suited to our various climates in East Africa, will be proceeded with after the war. The improvement of existing native vegetables, particularly spinach plants should be included in the scheme.

CORRECTIONS

In October, 1943, *number*—

(1) The foreword on page 61 contains the following sentence. "The early ley experiments in East Africa were carried out with imported grass species from temperate regions and, as might be expected, were unsuccessful." Dr. W. S. Martin has pointed out that the word "Kenya" should be substituted for "East Africa" and "pasture" for "ley". He adds: "The earliest ley experiments in East Africa (if not in all Africa) were carried out in Uganda; almost entirely with indigenous grasses".

(2) Page 65. Table 2, the correction of 154.5 instead of 154.4 against *B. dictyoneura* should be in col. 7, not col. 4 as stated on page 126, Jan. 1944, number.

In January, 1944, *number*—

(1) Mr. W. V. Harris asks that the following, more up-to-date, formula should be substituted for that given under "Coffee Bug (*Antestia*) bait (7)" on page 164:—

Sodium arsenite: 2 oz.
Sugar: 5 lb.
Water: 4 gallons.

(2) The author of the short article on "Rice Cultivation" page 166, should have been given as J. T. Moon, Agricultural Officer, Kenya.

(3) On page 142, line 20, in column 2, the sentence should read: "All these trees were predominantly female but some trees of all clones produced male flowers, and in three clones the males were opened at about the same time as the earliest female flowers, . . ."

APPEAL FOR BACK NUMBERS

We have been asked to make special efforts to obtain copies of Vol. 7, No. 1, of the *East African Agricultural Journal* for Government libraries in Holland that will be rehabilitated after the war. The number is wholly out of print and it will therefore be appreciated if anyone possessing a copy that he does not want will post it to the Government Printer, P.O. Box 128, Nairobi. Cost and postage will be refunded to the sender.

CORRESPONDENCE

WOODEN TYRES FOR FARM VEHICLES

Plateau, Kenya,
8th December, 1943.

The Editor, East African Agricultural Journal

Sir,

Here are some notes on the use of wooden tyres for farm vehicles.

The rims are of the heavy lorry type, 20″ diameter, flat, and 5″ wide inside the flanges, one of which is of course loose. Each tyre is cut from ten blocks, each 9″ × 5″ × 10″ long. I used dry mueri (*Pygeum*), but I think that either red thorn (*Acacia laliae*) or satinwood (*Fagara*) would be better. Msharagi (*Musharagi*, Olive) is useless, as it splits. The blocks are shaped in segments of a circle, making them of such size that the outside diameter of the tyre, when assembled on the rim, is 35″. There should be a space of about $\frac{1}{2}$″ between each two adjacent blocks. Two flat iron rings are made of $\frac{1}{4}$″ × $1\frac{1}{2}$″ or 2″ flat iron. Each ring is 27″ outside diameter. Ten equidistant holes $\frac{9}{16}$″ are drilled in each ring, the two rings being drilled together, to be sure that the holes match. The shaped blocks are assembled on the rim, and tied tightly in place with a reim. Now one of the iron rings is placed on each side, concentric with the rim, and $\frac{1}{2}$″ holes are drilled in the blocks. Finally the whole is bolted together with $\frac{1}{2}$″ × 7″ bolts. It is not necessary to weld the loose flange to the rim; in fact it is an advantage not to, as then the ordinary rubber tyre can be replaced, should occasion arise.

I have used this type of tyre on the back wheels of a heavy trailer with entire success. Each tyre costs about Sh. 25, as against Sh. 300 for a rubber tyre and tube. The draft is not greatly increased, at least in dry weather. I have yet to try them in the rains.

Yours faithfully,
W. L. JACKSON.

SOIL STRUCTURE

By W. S. Martin, Senior Chemist, Department of Agriculture, Uganda Protectorate

Introduction

The reapplication of ley farming or grass rotation has, until recently, been advocated for the purpose of improving pastures. Now the improvement of pastures has been found to be linked with a more fundamental improvement, that of the soil. In Uganda the grass rotation was adopted because of its good effect on soil structure, which in itself is an important soil conservation factor. It is the purpose of this paper to define soil structure, to discuss its measurement, to give some of the results obtained in the past decade and their application to the grass rotation.

In agronomic literature the terms *texture*, *structure* and *tilth* have often been used in a haphazard fashion causing some confusion as to their real meaning. The standard application of these terms is as follows:—

Texture refers to the size-distribution of the ultimate soil particles (as revealed by mechanical analysis) superimposed on the farmers' terms for soil class, i.e. clays, loams and sands with their intermediates heavy loams, sandy loams, etc. The texture of the soil is permanent except for the changes brought about by sheet erosion.

Structure indicates the aggregation of the ultimate particles into larger water-stable compound particles known as crumbs. Crumbs contain varying proportions of clay, silt, sand, etc. Unlike the texture, the structure of the soil can be modified by various cultural operations.

Tilth is a practical agricultural term referring usually to the state of the seed bed. For fine seeds a fine tilth is necessary, for large seeds the tilth need not be so fine. Whilst tilth is a function of both texture and structure it is most profoundly influenced by the timing of cultural operations. The soil must be at exactly the right state of moisture when the implements are put in. If too wet the soil may be puddled and big clods result; if too dry, then existing crumbs are pulverized, leaving a fine dusty seed bed. The range of moisture content within which it is safe to cultivate varies with the soil's texture and structure. The heavier the soil the narrower this range and the better the structure the wider the range. In this respect an ounce of practical experience is worth a ton of theory. The observant farmer knows his own land and is the best judge of when to operate. Mechanical analysis (texture) is no real guide because the type and therefore the cohesive properties of different clays vary. Although many East African soils are heavy clays or clay loams by mechanical anaylsis, they can safely be worked in a wetter condition than soils of a similar textural character in temperate zones, because the fine fraction here consists largely of the hydrated oxides of iron and alumina, whilst that of temperate zones is a true clay—much more reactive.

Texture then, except under conditions leading to serious sheet erosion, may remain unchanged for comparatively long periods, while structure is by no means static; crumbs are continually being formed or broken down by various tillage operations, usually so slowly as to be hidden from any but the trained eye. Tilth on the other hand, although in part a function of texture and structure, may vary from season to season, or even from crop to crop, according to the timing of inter-crop cultivations relative to the field moisture-content.

Soil structure and rainfall penetration.—I have already defined structure as the state of aggregation of the ultimate particles into water-stable crumbs. It is not difficult to imagine the difference that crumb formation makes to the body of the soil. A soil with no crumbs would have a very small pore space and all the pores themselves would be equally small resembling in this respect a bottle of a very well known stomach powder. Water, poured on to the surface of a soil in this condition, would penetrate very slowly indeed; all the finer soil fractions would be filling the spaces between the coarse fractions and the finest of all might even swell and choke the whole system. A soil of precisely the same mechanical analysis but of good structure presents a different picture. Not only are there pores of the same calibre as those discussed above *within* each crumb but much larger pores *between* the crumbs allowing water to penetrate quite easily. For demonstration to agricultural staff, students and others I usually arrange three glass jars one filled with soil of good structure as it comes from the field, the second with the same soil broken down to pass a 3 mm. sieve and a third with the 3 mm. sample ground in a wooden mortar with pestle of wood. These specimens while obviously of the same *texture* have a changed *structure* as is shown when equal volumes of water poured simultaneously on these soil surfaces penetrate at amazingly different rates. Any reader can find supporting evidence by comparing, on land which has recently been opened from bush or grass, and on similar land cultivated for a long period, the depth to which water has penetrated after the first good rain subsequent to a long dry period.

Soil structure and aeration.—One of the first principles in agriculture is that adequate aeration of the soil is essential to fertility. Whilst the truth of this principle is not disputed the frequent turnings practised to achieve this

aeration are seriously questionable. In actual fact these cultivations have often succeeded in pulverizing the soil, reducing its structure and slowing down air movements. Just as good structure facilitates rainfall penetration it equally improves aeration, because water percolating down through the soil after every storm must draw after it a new supply of fresh air. The air charged with carbon-dioxide is driven down ahead of the rain water which cannot leave a vacuum behind it.

Soil structure and erosion.—The connexion between the structure of the soil and erosion is clear. Rain falling on a soil of a good structure penetrates quickly into the deeper layers and is there held ready for plant use. The poor soil provides no easy ingress for rain water which quickly saturates the surface inch or two and then sets off down any slope there may be carrying clay and humus with it. Not only is water lost but valuable binders and nutrients go with it. Some people might think that some loss of water is immaterial in a country of from 40-60″ of reasonably well distributed rainfall, but temperatures are high, particularly between storms, and cause high rates of evaporation and transpiration. Complete absorption of rainfall is necessary for soil conservation, both for the plants and to keep up the underground water supplies. At the same time free percolation of water must improve aeration so that there is never likely to be undue accumulation of carbon dioxide.

Soil structure and the plant.—A soil of good structure is a medium allowing for full root extension of the crop. I have found thick, easily recognizable, roots of elephant grass and sugar cane at depths of six and eight feet in soil profiles. I have no doubt that fine roots could be found at greater depths by careful washing out. Some of the heaviest yields of sugar cane obtained in this country have been on soils of low nutrient content but of first-class structure.

The picture is clear then. In a compact powdery soil root range and rainfall penetration are equally restricted. The plant draws its food from a relatively small volume of surface soil and relies for survival on regular rainfall because there are no water reserves below. With improved structure roots extend, water penetration increases, and the plant can draw the nutrients and water it needs without being so dependent on ideal rainfall conditions. This is a most important consideration in East Africa.

Early Experiments

The maintenance of soil fertility has been an agricultural problem of first importance from time immemorial. The main advances towards its solution were made under temperate conditions in the northern hemisphere as was only natural in view of the parallel advances in population, education and, in the past century, agricultural science. The solution there was found to be the rotation of crops with a good dressing of farmyard manure added once in a cycle. All the agricultural text books, written as a result of experience in temperate zones, stress the value of organic manures in lightening heavy soils and adding "body" to light soils. Later, the discovery that the root organisms of legumes fixed atmospheric nitrogen, led to the advocacy of green manuring with leguminous crops to obtain the dual benefits of organic matter and added nitrogen. There is no doubt that in suitable circumstances spectacular results have been achieved by applying these principles and the position of the green manure was pre-eminent when widespread agricultural experiments were started in the tropics after the 1914-1918 war. With this background it is not surprising that in Uganda, as elsewhere in the tropics, when it was necessary to replace shifting cultivation by a less wasteful agricultural system, the main emphasis in all the rotations tried was on the green manure with which was often coupled farmyard manure or compost. The results from green manuring did not show the hoped-for increases in yield. On the whole the failure of these rotations in Uganda was because the cultivation destroyed the soil crumbs. In this respect the green manure was a bigger sinner than farmyard manure which, without damage by extra cultivation, maintained and even improved yields of some crops. But farmyard manure alone could not maintain soil structure and therefore failed to stop erosion.

Observations on grass and structure.—In Uganda, while concentrating particularly on the problem of soil erosion, I found several clues which pointed to the fact that soil structure is an important factor in the stability of the land. Arable land in the areas of heavy elephant grass was seen to be much less easily eroded than land in short-grass country, but had lost this property of resisting erosion after years of cultivation. In 1928 two soil profiles were exposed within a few yards of each other on the same soil type. One under a good stand of elephant grass had 15-18 inches of dark top-soil of excellent structure and was full of

roots many of which extended six feet and more into the subsoil. The other after ten years of cultivation showed 4-6 inches of rootless dusty grey top-soil and subsoil as compact as soap with no sign of root. This cultivated land had already suffered serious erosion for reasons similar to those already explained. The other soil on clearing showed ample pore space down to more than a foot, below that depth there were plenty of old root channels to dispose of any excess of water.

Again, at that time, we prepared cotton demonstration plots in pairs in the Eastern Province. The "good" plot was ploughed and cleaned before sowing, and the "bad" plot was just rough-ploughed. In Teso, particularly, this "bad" plot usually had clods and weeds and looked very rough indeed with *Imperata cylindrica* growing freely. Both plots were weeded after germination, the first carefully with all clods broken and *Imperata* removed, and the second more carelessly. Thereafter the "good" plot was kept quite clean and the "bad" plot weeded much less frequently. The curious thing was that the cotton on the "good" plot was almost invariably poorer than that of the "bad" and indeed than that of the native plots in the vicinity. The answer was, as it is always in the case of over-cultivated land, that the surface of the carefully prepared plot was quickly smoothed and caked by implements and rain so that water penetration was reduced and run-off increased. The rough plot on the other hand did not cake so easily and the rain was held in the land to the benefit of the crop. In other words, on the "good" plot cultivations and hard rain between them had caused such a deterioration of soil structure that the crop suffered. This lesson was not long unheeded; rough preparation of land was encouraged for big-seeded crops, and later weedings reduced. It is interesting to note how closely this is in accord with the findings of Keen, Russell and others in their "Studies in soil cultivation" over a period of years from 1930.

All the field observations in this country pointed to the fact that it was the physical, rather than the chemical, nature of the soil that determined fertility. To obtain further information on this point the main replicated experiments were sampled and analysed for calcium, nitrogen, phosphate, potassium and carbon. In no case was there a significant correlation between nutrient and yield even on a 288 plot uniformity trial. It would appear therefore that, at Serere, no essential plant nutrient was so lacking as directly to affect yield. This does not mean that a judicious dressing of nutrient in some form or other would not increase yield, particularly if the addition happened to be of a balanced manure like farmyard, but it does mean that other factors are more important.

Adoption of grass rotation.—Following the initial observation of the effect of elephant grass on soil structure, already mentioned, work was continued along these lines concurrently so that when the major field experiments had proved (1924-33) that the rotations and legumes had not maintained soil fertility we were prepared to substitute the grass rotation which is, after all, only the native shifting cultivation accelerated and remodelled.

In 1934 then, the main focus of the field experimental work in Uganda was changed from the manurial to the soil-structure aspect of the rotation and to possible combinations of the two. Grasses assumed greater importance because it became necessary to find out their effects on soil structure in order to decide which grass would serve best as a resting cover. It was also necessary to discover the best periods of rest and of cultivation after rest. The value of manure and legume could not be ignored. The food value and palatability of the resting cover had to be taken into consideration because from the first it was hoped that the grazing animal could be used on resting land, to consolidate and manure it, without calling for too much extra time and labour from the peasant farmer.

EXPERIMENTAL PROCEDURE

To answer the above questions it was necessary to carry out a number of properly designed field experiments. At the same time it was equally important to decide on a laboratory technique for estimating the structural qualities of the soil. It was desirable that this laboratory method should be rapid and reasonably accurate because, after having been proved on replicated experiments, it would be the main instrument for the study of the resting and cultivation requirements of the soils of the Protectorate. A large series of 1/40th acre grass plots was laid out in Kampala (and at Serere and Ngetta) to gain some idea of the relative effects of different grasses on structure. Three years after establishment soil profiles were exposed, photographed (*see* plates I and II) and sampled. These samples were used for the preliminary experiments in laboratory technique. They were examined for pore space and other data by the Keen-Raczkowski (1921) box method, for sticky point by the method of Hardy (1923)

Keen and Coutts (1928); and later water-stable crumbs by a modification of the method of Tiulin (1928). The box method takes rather a long time and the results obtained vary with the technique of the operator. Sticky point, as will be shown later, is a measure of colloid content and is therefore closely related to the inherent crumb-forming power of the soil type: but not necessarily with the actual number of crumbs present at a given moment because the wetting and kneading inseparable from the method of determination must break down some crumbs which would be stable in the normal soil-water regime. From theoretical and practical considerations the wet sieving method of Tiulin is the most logical way of approaching problems of soil structure regeneration. By sieving the sample in water it is assured that only water-stable crumbs are taken into account. The method has given good reproducible results in the hands of African workers and is the normal method of examination adopted in these laboratories. Air-dry samples weighing 100 gm. passing 3mm. are wetted overnight by capillarity and then transferred to a bank of sieves of mesh diameters 2 mm., 1 mm., and ½ mm. The bank is moved up and down in a four-gallon petrol tin of water until the top sieve is "clean". The top sieve is then removed and the motion repeated until the next sieve is finished. Finally the suspension in the tin is poured through 100-mesh and 200-mesh sieves, all the samples are air-dried, weighed and the weights expressed as percentages. For most purposes it is sufficient to take into account only those crumbs over ½ mm. in diameter because the smaller aggregates are not as a rule of any benefit to the working properties of the soil in the field. 100- and 200-mesh fractions contain a higher proportion of simple particles. These fractions, therefore, if included in structure analysis, must be further subdivided into crumbs and simple particles. All we need here is a rapid and accurate method of assessing soil structure in order to define the state of the soil in any area in the cultivation–rest cycle, as based upon the results obtained from soil types of known cultivation history.

Table I gives the grasses of the Kampala series in the order of their powers of soil regeneration as revealed by the wet sieving method. The range in crumb percentage is from 22 per cent to 47 per cent although the plots were quite small and within one acre on fairly level ground. The differences in root range and aggregating power of the grasses indicated in the photographs are confirmed by the wet sieving data. The Ngetta results in Table II bring out similar differences in that two years of rest under *Cynodon* are more effective in crumb formation than three years resting under *Sporobolus*. The Ngetta figures also show the destruction of crumb structure by cultivation.

TABLE I

KAMPALA GRASS PLOTS

Grasses arranged in order of regenerative power as revealed by the wet sieving method

Cover	Crumb over 0·5 mm. Wet sieving	Order in power of regeneration. Wet sieving data
	Per cent	
Setaria sphacelata (Ngetta) ..	47·6	1
Brachiaria decumbens ..	45·7	2
Brachiaria platynota ..	41·2	3
Beckeropsis uniseta	41·0	4
Panicum maximum	40·8	5
Hyparrhenia cymbaria ..	40·7	6
Brachiaria brizantha ..	39·1	7
Pennisetum polystachyon ..	35·6	8
Loudetia kagerensis	35·4	9
Cynodon dactylon B. (I) ..	33·1	10
Cynodon plectostachyon B. *	32·6	11
Cynodon dactylon A. (I) ..	32·4	12
Cynodon plectostachyon A. *	31·7	13
Sporobolus filipes	30·7	14
Paspalum notatum	30·5	15
Sporobolus pyramidalis ..	30·2	16
Themeda triandra	30·0	17
Cynodon transvallensis ..	29·0	18
Brachiaria soluta	28·8	19
Chloris gayana	28·8	19
Paspalum conjugatum ..	28·7	21
Pennisetum rupelli	28·3	22
Rhynchelytrum repens ..	28·1	23
Erichloa procera	27·8	24
Exotheca abyssinica ..	26·9	25
Setaria splendida	26·2	26
Melinis maitlandii	26·1	27
Eragrostis mildbraedii ..	25·1	28
Hyparrhenia sp. (Kampala)	24·9	29
Hyparrhenia filipendula ..	24·8	30
Hyparrhenia rufa	24·4	31
Paspalum auriculatum ..	22·8	32

*These are strains of *Cynodon* which have been collected from different parts of the country. The only real difference is one of size, *Cynodon dactylon A* being the smallest and *C. plectostachyon B* the largest of the group. It is interesting to note how close they are in the table, indicating that in soil structure development they are as closely allied as they are botanically.

A preliminary account of the ley experiments at Ngetta has been published by Martin and Badcock (1937). The main area of this station is under a 6-course rotation in which three years of rest, under grass, follow three years of cultivation. The area is divided into six blocks, each one of which is under a different course of the rotation, so that all phases of the rotation are represented each season. There is no doubt that since this rotation was established the fertility of the farm has been maintained and even improved: it is within this

rotation that trials have been made on the establishment and grazing of the resting cover. Much of the earlier work was concerned with seeded pastures, the seed mixture used on Blocks C to F of Table II consisted of:—

	Lb. per acre
Pennisetum polystachyon	9·0
Setaria sphacelata	8·5
Brachiaria decumbens	3·0
Setaria aurea	1·5
Hyparrhenia filipendula	6·0
Hyparrhenia rufa	2·5
Panicum maximum	0·5

Block A was seeded to *Sporobolus pyramidalis* in pure stand. Three years after seeding, soil samples were taken for analysis by the wet sieving technique. *Cynodon* had invaded in patches but otherwise the *Sporobolus* had held its own. Block B was left to natural regeneration with grazing. The result was that a complete cover of *Cynodon plectostachyon* was quickly established. The structure analyses are given in Table II where the course in the rotation when the plots were sampled is indicated under "Treatment".

TABLE II

NGETTA—Effects of cultivation and resting period

Block	Treatment	Crumbs over 0·5 mm.	Resting cover
		Per cent	
A	Three years' grass after three years' cultivation.	28·08	Seeded *Sporobolus pyramidalis.*
B	Two years' grass after three years' cultivation.	34·33	Natural regeneration. (*Cynodon plectostachyon.*)
C	One year's grass after three years' cultivation.	24·75	Seed mixture.
D	One year cultivation after rest.	24·84	Seed mixture.
E	Two years' cultivation after rest.	25·87	Seed mixture.
F	Three years' cultivation after rest.	22·59	Seed mixture.

Wet sieving analyses of soils in good condition have shown that soil types at different stages of resting and of cultivation contain varying percentages of crumbs. Thus Bukalasa land under elephant grass shows over 60 per cent, a figure which was reduced by cultivation, over a period, to 30 per cent. Soils at Barberton (South Africa) and Serere gave 50 per cent and 40 per cent under grass but there again the crumb content was reduced by cultivation to 30 per cent in each case. By examining a large number of samples of soils of different types and known cultivation-history it should be possible to build up a reference collection on which to base the degree of degeneration of any sample analysed for advisory purposes. This would necessitate a vast amount of exploratory and analytical work before any sound advice could be given. While these data are being collected some other criterion is necessary to assess the structure potential of any soil in addition to its actual crumb content as determined by sieving in water. Sticky point, already mention in the preliminary experimental work, best serves this purpose.

Sticky point and structure-forming capacity.—The mechanics of crumb formation are as yet far from clear but, whatever the forces involved, it is evident that crumbs cannot be water-stable without some form of binding material which is certainly colloidal. The soil colloids are clay and humus. Owing probably to the wide differences in quality or cohesiveness of various clays the usual determination of clay by mechanical analysis does not give sufficiently precise information on the crumb-forming capacity of a soil. (Boulder clay is much more cohesive than the hydrated oxides which normally make up the bulk of the clay fraction of the local red loam.) Similarly the estimation of organic matter from carbon content does not produce an expression of the colloidal property of the organic fraction. The sticky-point method of Hardy was shown by Keen and Coutts (1928) to be largely controlled by the organic and inorganic colloid; a "single factor" expressing total active colloid content.

The sticky point is defined as "the point at which a thoroughly kneaded plastic mass of the soil is just about to stick to the fingers or to a knife" or "the point at which kneaded moist soil just ceases to adhere to external objects". In practice the critical point is surprisingly sharply defined and good duplicates are consistently obtained in this laboratory by the African staff. About 15 gm. of dry soil are thoroughly moistened in the hand and kneaded until the wet soil no longer sticks to the hands, when it can be quickly worked into a small pat and weighed. After drying at 105°C the pat is weighed again and the moisture percentage at the point of stickiness is the "single value" factor. The lower limit of sticky point in local soils is between 14 per cent and 16 per cent. The results at this point are apt to be unreliable because the soils are coarse-grained sands and often contain so little colloid that it is difficult to judge the sticky point or even to make a pat sufficiently stable to weigh. As the sticky point increases in value its definition in practice is clearer and the re-

sults are more reliable. The results obtained from some African soils in good heart are given in Table III.

TABLE III

RELATION OF CRUMB PERCENTAGE TO STICKY POINT OF SOME AFRICAN SOILS IN GOOD CONDITION

Soil	Water-stable crumbs over ½ mm.	Moisture at point of stickiness
	Per cent	*Per cent*
Bukalasa, Uganda	60	32·9
Barberton, South Africa ..	50	24·2
Serere, Uganda	40	22·3
Ngetta, Uganda	35	21·5
Lugongo, Tanganyika.. ..	25	19·6

It is clear from these results that there is a close relation between the percentage of moisture at the sticky point and the crumb-forming capacity of a soil; no amount of resting under grass could be expected to produce crumbs in soils of sticky point 16 or 17 but with rising sticky-point values the percentage of crumbs also rises.

Like wet sieving the sticky point is a simple determination and it seems possible that these two methods will give us the actual and potential crumb percentages respectively. This aspect of the work is being continued.

Results of field experiments.—The results of long-term replicated experiments on soil structure and manuring in Uganda have been summarized to date for publication elsewhere (Martin 1943). They include results from the Serere Fertility Experiment the plan of which was discussed in this Journal by Martin and Biggs (1937). They established the fact that cultivation reduces, and resting under cover cover builds up, the crumb structure of the soil.

The Uganda experiments indicate that organic manures, in the form of farmyard manure, cotton seed or green manure, do not have any significant effect on soil structure. The explanation of this rather unexpected result may be that, under temperate conditions the end-point in the breakdown of most of the added organic matter is humus, whilst in well drained humid tropical soils the breakdown is so rapid that little of the organic matter ever reaches colloidal dimensions. Apart from more rapid oxidation by micro-organisms owing to higher temperatures, termites would also play a big part locally in the destruction of organic matter.

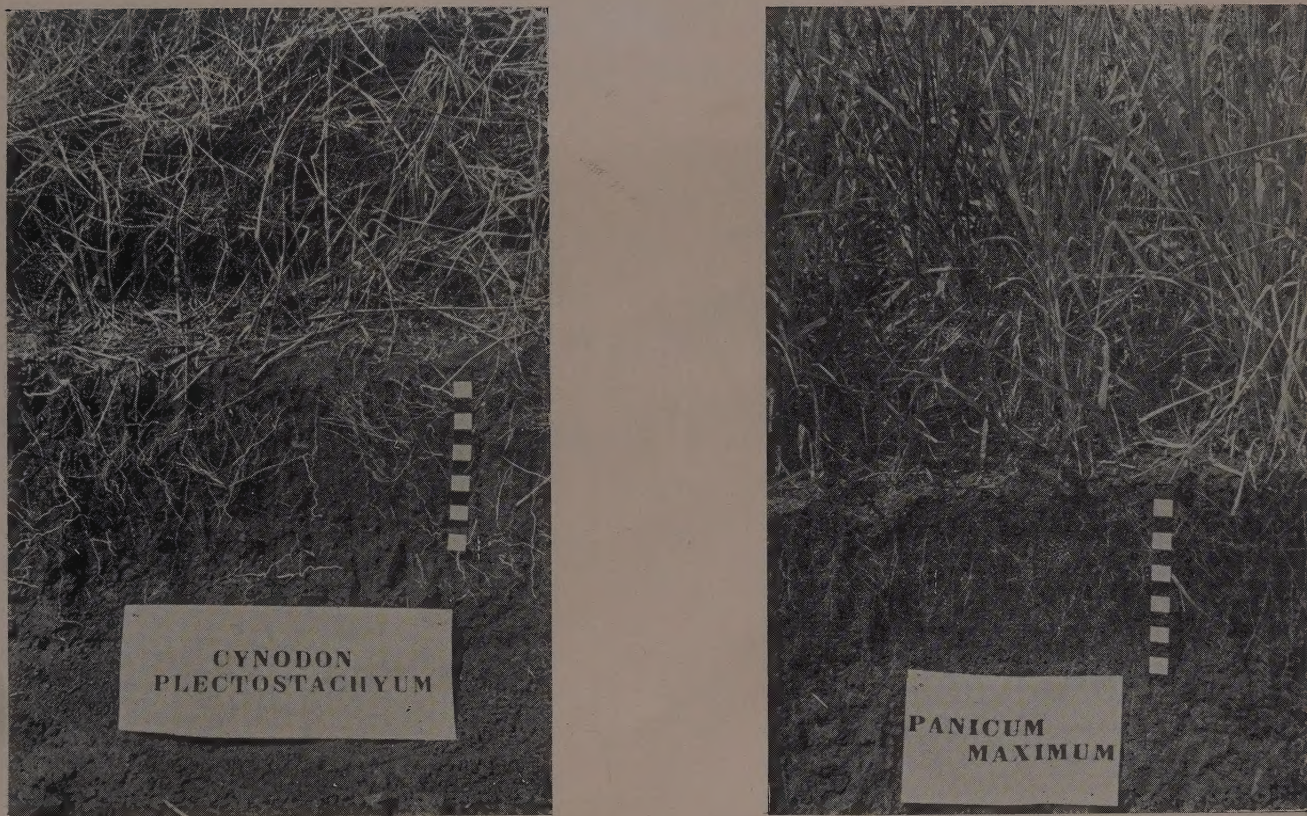
It is well known that lime has the power of flocculating clay, and the practice of liming heavy soils to improve their working qualities dates from the beginning of the Christian era. There is no doubt whatever that in temperate regions liming is beneficial but a ten-year experiment at Serere has shown that lime with or without green manure has no significant effect on either structure or yield there. The nature of the clay fraction of local soils and the rapid destruction of organic matter already referred to may account for these results but more definite reasons cannot be assigned until further work has been done on the mechanics of crumb formation.

Although it has been shown that organic manures are comparatively ineffective in structure regeneration they still have their place as crop feeders, often giving economic increases in yield, so that if they can be used *within the grass rotation* so much the better.

PRACTICAL APPLICATION

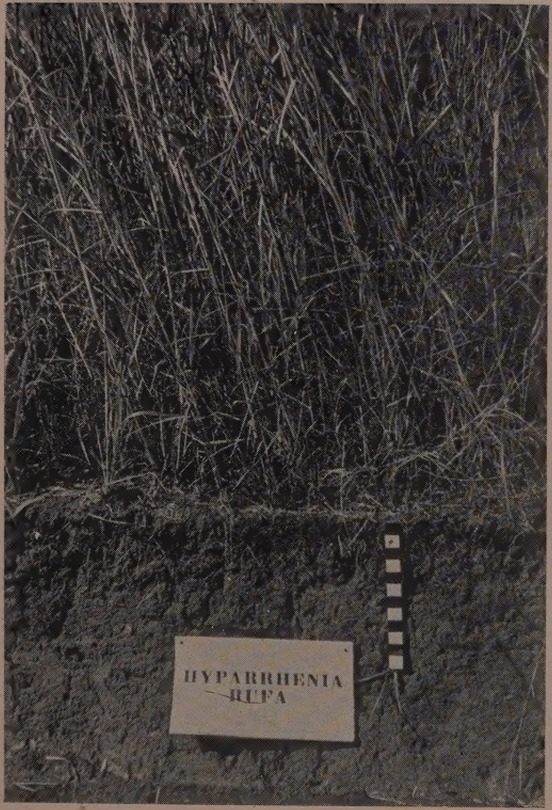
A note on the field application of the above results has already been published by Kerr (1942). The broad principles enunciated in his paper could be applied to any arable holding whether it is reckoned in tens, hundreds or thousands of acres. First make sure that the soil has sufficient body to benefit from the grass resting-period. If there is any mineral deficiency it must be made good. Then study the local grasses, particularly those which appear quickly when arable land in fair condition is left untouched for a few months. In many cases natural regeneration will be quicker, easier, cheaper and more efficient than any artificial seeds mixture. Aid this natural process by taking care not to increase the recovery period by over-cultivation, thereby seriously breaking down crumb structure. Divide the arable land into blocks (contour strips if on slopes) of roughly equivalent area and arranged so that one block will be under each course of the rotation at one time and if possible that no contiguous blocks shall be in cultivation together. Each year one area goes to rest and a rested area is ploughed. A three-year period of rest followed by three years of cultivation will be quite safe to begin with so that six blocks will be necessary. The optimum period of rest and the best type of resting cover must depend on local conditions. Experiments on this aspect of the problem are still being carried out in Uganda but there is already some evidence that, once the land is in good heart, the resting period may be shortened and the period of cultivation

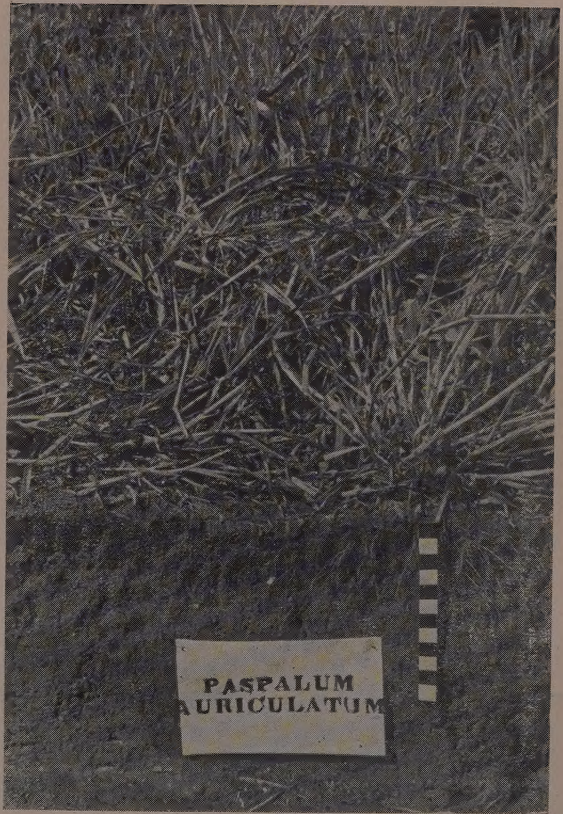
PLATE I



Grasses which greatly improve soil structure. Note the crumbly appearance of the soil within root range
(Black and white scale in inches

PLATE 2





Grasses which are less effective in crumb formation. No crumbs below about four inches as compared with the much greater depth of good structure shown in Plate 1

(Black and white scale in inches)

correspondingly lengthened. In cattle country, grazing of resting land can do nothing but good, provided that it is grazed lightly at first and progressively more heavily, always under strict control.

Kerr (loc. cit.) and Nye (1937) in referring to this grass rotation work in Uganda refer exclusively to elephant grass (*Pennisetum purpureum*). I would point out that this is entirely because this grass is indigenous over a wide area of Uganda. All grasses improve soil structure to some extent and it is possible that the hardier sugar canes would also be effective in crumb formation.

Particular care should be taken in areas where any species of couch grass is likely to become a menace. The elephant grass areas of Uganda are all too easily infested with *Digitaria scalarum*. It spreads rapidly in old cultivation and, except in thick shade, is difficult to get rid of. It can be kept in check here only if the elephant-grass resting-cover is planted thickly, like sugar cane, as soon as the final crop is off. The quick shading of the ground leaves the weed grass no time to spread. If there should be a gap between the removal of the last arable crop in the rotation and the planting of the resting-cover it would pay to remove couch in the interim. To maintain the soil shade the elephant-grass resting-cover should neither be cut nor grazed in its first year because of the danger of the weed spreading at its expense. In areas of thick infestation it would pay to grub out and burn as much couch as possible before planting the resting cover to ensure a quick getaway for the latter.

Summary

The terms "texture", "structure" and "tilth" are re-defined. Laboratory means of assessing actual and potential crumb percentages are given.

The use of the grass rotation and its practical application are discussed.

Acknowledgment.—It is a pleasure to acknowledge the excellent work done by a succession of Agricultural Officers at Ngetta in the last decade. Thanks are also due to Mr. A. S. Thomas for the soil profile photographs.

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WRITE SIMPLY

They said: A mulch brought about a greater conservation of moisture in the soil.

Try: A mulch kept the soil more moist.

They said: The young sprouts made the most rapid development at about 75°F.

Try: The young sprouts grew most rapidly at about 75°.

They said: This mole-rat greatly exceeds the Aberdares species in dimensions.

Try: This mole-rat is much bigger than the Aberdares species.

They said: Vegetable growing was conducted on a very limited scale.

Try: There was very little vegetable growing.

They said: The work of fixation of prices of imported goods is undertaken by Mr. X.

Try: The prices of imported goods are fixed by Mr. X.

We said (p. 61 this Journal Oct. 1943): Corrigenda and addendum.

Try (says a subscriber): Corrections and Addition.

PRODUCTION OF SEEDS OF TEMPERATE VEGETABLES IN EAST AFRICA

War-time efforts and Suggestions for the Future

By Capt. F. Hawkins, Dip. Hort., E.Ang.Inst.Agric.. Seed Specialist to Governments of Kenya, Uganda and Tanganyika

Introduction

The production of seeds of temperate vegetables in East Africa is, in many respects, still in the experimental stage, although an increasing amount of seed is being produced. We who are engaged on the work are learning new facts every day, frequently finding it necessary to modify or reject theories and practices which have been employed for decades in the established seed-producing areas of the world. It is, in fact, pleasantly startling when, on occasion, we find that some practice of the temperate seed-grower is also successful in the tropics, if modified either intentionally or by the sheer outcome of our ignorant blunderings, or by an act of God.

I was tempted, therefore, to wait until at least the end of the war (when our knowledge might be more complete) before writing any record of our efforts and observations, but should this article, which is intentionally limited to problems which have particularly interested us on this task, prove of some use now to other workers on a parallel path, I make no apology for reporting on a half-completed job.

1.—Object, History and Policy

In war time, certain sources of supply of many commodities are suddenly and completely cut off, whilst at the same time demands for those same commodities become vitally imperative in the most unexpected and unprepared areas of the world. It would be paradoxical to wish that we might have foreseen these difficulties and have countered them in time, for such planning—of necessity completely world-co-operative—envisages some hypothetical future when world-wide economic and social balances are adjusted satisfactorily and our Brave New Scientists have evolved a method of roguing potential Hitlers at—or before—germination.

The Empire-wide organized scheme for each country to produce, or to try to produce, her own requirements of seeds of temperate vegetables, firstly to supply her own needs and secondly to assist less favourably situated neighbours, did not begin until the latter half of 1942. At that time, as far as East Africa is concerned, apart from the bean seed-growers of Arusha (who now export some 1,000 tons per annum) practically nobody was producing seed on any noticeable scale. People with seed-growing experience were very scarce, and literature on the subject was, with a few exceptions, non-existent. One notable exception was the very timely and informative article "Vegetable Seed Growing in East Africa" by A. G. G. Hill, in this Journal, July, 1942 (Vol. VIII, No. 1), which proved an extremely sound basis upon which to build our plans for inducing long-day and cool-loving plants to grow and reproduce themselves successfully on the equator. Since then, the Imperial Agricultural Bureaux have issued Joint Publication No. 5, "The Production of Seed of Root Crops and Vegetables", dated July, 1943. I hope this will be revised and a further issue made in 1944, as it is a valuable collection of reports on the seed-growing efforts of the whole Empire.

Mr. T. H. Jackson, of the Kenya Department of Agriculture, was given the task of establishing experimental work, including field varietal trials, at Njoro in Kenya. He also entered into contracts with farmers in the Kenya Highlands, at altitudes varying from 5,000 to 10,000 ft., to grow seeds for the Agricultural Department, who would share the harvests with Uganda and Tanganyika, they being jointly interested in the scheme. The work began in the middle of 1942, but most of the sowings had of necessity to wait until the short rains should begin. Unfortunately that year the short rains failed. One result of the lack of sufficient rain was that many of the 1942 sowings had not flowered or produced seed when the 1943 long rains were upon us. There was, therefore, little "to go upon" as regards what results to expect from the projected 1943 sowings, or what kinds and varieties we should concentrate upon, but there were slight indications, so we forged ahead, hoping for the best, with little or no choice of varieties of stock-seed.

The intention was to produce one generation of progeny from imported seed, and, if the resultant crops showed degeneracy to any extent, to import fresh seed for the following

year's stock. Bulk production, so far as quality admitted, was the aim.

On the writer's appointment as Seed Specialist, in February, 1943, this increase of staff allowed for expansion to about 200 acres, which is now being further increased to approximately 250 acres, chiefly by the addition of irrigated ground. This may not appear to be an area commensurate with the size and requirements of the combined territories of East Africa, but a large number of gardeners, farmers and Agricultural Stations are producing some of their seed requirements "privately", in addition to the scheme organized by the Kenya Department of Agriculture. The scope and speed of the development of our project are largely determined by the limited number of skilled staff and of farmers with seed-growing experience.

A Seed Station, which is the administrative centre, was established by the Agricultural Department at Turi, at 7,700 feet, where the rainfall is reputed to be well distributed (receiving short rains which some other areas miss) and amounting to approximately 48 inches per annum. The soil is for the most part good forest loam. Frosts occur on clear nights during the dry hot season of December-March, chiefly in the hollows. This station comprises some 60 acres. As far as the usual run of vegetables are concerned, the whole range grown here compares very favourably with the quality obtained in the drier counties of England. (I do not here refer to their reproductive abilities.)

2—Temperature, Light and Water

These three factors have proved to be completely interdependent in their effect upon the plant. Once it has reached vegetative maturity (fit for the market), a plant which is retained for seed production must have these factors in correct proportion, and at the right time and place, or it will merely grow fatter, and uglier, until it reaches a static half-rottenness which may last for over twelve months, by which time the farmer would probably have decided to grow pyrethrum or some similarly remunerative crop in its place.

But how are we to assure these necessary conditions at the right time and place? I will deal briefly with the last factor, water, first. The plants require moisture at the roots early in life to allow of reasonably speedy and healthy growth. When they have reached vegetative maturity they can do with, and often benefit by, comparative dryness to facilitate the ripening and "resting" period. To awaken them from this phase, comparative coolness and moisture at the roots is desirable or even essential. At the flowering stage a sufficient supply of water is necessary to make good strong heads. Very soon after this, little or no water is required and may, in fact, be the cause of root-rots and poor seed-ripening if applied too generously. The only sure method of controlling the water supply is to grow under irrigation, especially in countries that are subject to prolonged droughts. Why is water interdependent with temperature and light? Because its presence or absence effects the temperature of the soil and atmosphere, and also because it is a factor which times the growth of the plant in relation to the hot and the cool seasons.

The effects of temperature and light, especially as regards their influence in promoting reproductive development, have been the subject of much research since Gassner discovered that by subjecting germinated winter cereals to a temperature just above freezing point for a period of 30 days before late sowing, they flowered nearly as early as spring varieties sown at the same time, although late sown winter varieties usually failed to flower in the same year. Since then (1918), many workers have entered this field of research, while Garner and Allard and others working on the effect of day-length, have found that the two factors, heat and light, at least overlap—even if they are not at all times completely interdependent. An excellent article appeared in the *New South Wales Agricultural Gazette*, dated 1st February, 1943, giving a résumé of the most up-to-date knowledge on this subject, entitled: "The effect of length of day and temperature on the flowering, seed production and growth of vegetables". But even with this literature at our disposal, we find very few cut-and-dried rules for us to follow when growing temperate vegetables in the tropics, where neither the temperatures nor the day-lengths bear much relation to the regions where most of these workers carried out their experiments. We have conclusively proved, however, that temperature and water are far more important factors than length of day, in the majority of the vegetables we have grown. This is fortunate, for we can select relatively cool altitudes but we cannot—on a practicable scale—alter the day-length. If the vegetative stage of the plants' growth is completed by the time we get the cold nights of the hot season, many will form flowers, whilst some individuals will hang fire until the arrival

of the long rains, perhaps three months later. Four questions arise:—

(i) Are the diurnal cold extremes, in spite of the extreme heat of the days, a satisfactory substitute for a temperate winter?

(ii) Is the cool period of the wet season, during which the daily range is not so great, better than the hot season?

(iii) Is the presence of moisture in ample quantities in the soil, at the roots and in the air, a factor as important as, or more so than, temperature?

(iv) Why do some individuals of a batch flower months after the others?

Based upon our short experience of seed production in the tropics, I tentatively offer the following answers:—

(i) Diurnal cold extremes appear to be adequate, provided the soil is not bone-dry.

(ii) The wet season has a similar effect as cold weather, but we do not know whether temperature or moisture has the greater influence.

(iii) Both coolness and moisture are essential —probably equally.

(iv) In some cases differences in time of flowering may be due to slight inherent differences in the individual seeds, but probably are often caused by differences in soil conditions in the nursery or field.

Vernalization, the process of subjecting germinated seeds to temperatures a little above freezing point for days or weeks before sowing, has the effect of giving the plants an artificial winter and in some cases of promoting early flower formation. But this operation appears to be unsatisfactory for most of our temperate vegetables, which reach vegetative maturity weeks or months after germination; it is at this mature stage that the very important work of roguing and selection must take place and when the "cold spell" is really wanted to induce the flower-formation. Vernalization certainly cuts down the period of vegetative development and also alters the nature of that development, making it very difficult to fix reliable standards for selection. The present impossibility of obtaining thermostatic controls for refrigerators adds to the unreliability of this method for our immediate purpose. Such work may perhaps be done perfectly on a small scale in a laboratory, but it is a vastly different matter when attempted on a large scale in the field, fifty or a hundred miles from an electric main.

It seems, therefore, that we must take what temperatures and light God happens to give us, in the commercial seed-growing field, and try to make our crops fit in to the seasons—largely by the aid of irrigation.

3—What are "Temperate" Vegetables?

The special task we were instructed to carry out was to produce seeds of temperate vegetables. A list of the kinds and of the quantities required was given us. The list included all the most important of the kinds grown in English gardens. But how many of these are strictly temperate in origin? Will they all respond similarly to the tropical environment? Several, including beans, tomatoes and New Zealand spinach, appear to thrive much better here, both vegetatively and reproductively, than in Europe. Again, there are differences in adaptability or suitability between the varieties of any one kind of vegetable. The word "temperate" is a very general and arbitrary term in this case. For instance, cauliflower is classed as temperate, but it is doubtful if Early Patna variety would be a general success in England. Nor, indeed, are tomatoes happy in England in most seasons unless given artificial tropical conditions in a hot-house. But as all kinds are required to be grown here, we are left only with the choice of varieties, and at present, of course, we have to be content with whatever happens to be sent to us.

The varieties most suited to tropical conditions are, almost without exception, what the English gardener terms "early" varieties. Early and forcing varieties are usually grown in the shorter days of the temperate regions, often under artificial heat, and thus are known to succeed in conditions approximating to those in the tropics. They are almost sure, therefore, to be able to complete their vegetative growth here, which is half the battle, and there is no evidence to suggest that they are at a disadvantage in proceeding to the flowering stage.

Some kinds and varieties of "temperate" vegetables obviously originated, then, in non-temperate regions, or under partly artificial conditions not typical of temperate areas, whilst others thrive only when given an environment with some or all of the characteristics of an almost arctic climate. Knowledge of their origins should, therefore, be a help in estimating their potentialities in, and probable reactions to, the tropics. Unfortunately such

information does not appear to be available, here and now, so that we are left to guess their probable origins by their known like or dislike of cold weather when grown in, say, England. This is, I think, a sound guide, for the most tender plants grown in a temperate region are in all probability from a warmer clime, where also the day-length is short. English winter-hardy kinds, and those which are termed "maincrops" which mature in late autumn, should be given a cool altitude if we are forced to grow them in the tropics. In any case we are compelled to disregard their day-length requirements.

4—Stock Seed, Roguing and Selection

The progeny of a fixed cross has all the potentialities of reproducing successive generations of similar plants. Mutations, "sports", climatic influences, and especially contact with pollen from other varieties of the same species, will cause variations from varietal type. This stock seed, which may have been obtained either by multiplying from a specific cross, or by roguing and selecting from some originally heterogeneous "strain", must be kept true by continuous removal of "off types", and by keeping only the most perfect specimens for production of the next generation. Stock seed is usually grown separately from the ordinary commercial fields (out of pollen range) but may be augmented, improved, and in some cases entirely replaced by, selections from the commercial fields. Such highly skilled work of jealously guarding and improving the stock is a routine long-term policy of the peace-time seed-grower. We in the tropics must, however, be content with such stock seed as we may obtain (often of an unknown variety and of dubious trueness to any observable type) and adopt the short-term policy of roguing-out the obvious undesirables and retaining a fairly uniform mass for multiplied reproduction. We must be content with this method only, let us hope, for the duration of the war.

5—Adaptability, Acclimatization

As previously stated, some kinds and varieties are better adapted to tropical conditions than others. Probably many varieties, quite unknown to us at present, would be very suitable here for both edible and seed production purposes. During the war the possibility of obtaining seed of innumerable varieties and of testing them in the field is remote, and therefore we cannot hope to get very far with this aspect of the work until after the war is over. I suspect, however, that colonial public opinion will then, paradoxically, be little in favour of any such organized trials, for, in addition to the public's probable reaction to all "organizing", they will state that in any case they can, in peace time, obtain any kind of seed when they like, as much as they like, and from whom they like. And that would be largely true. Each man would follow his own fancy, buying a fresh lot of seeds from a temperate country every year, and everybody would be happy. But such a hand-to-mouth method, in itself, will never acclimatize the varieties to this part of the world, much less produce strains which may well do even better than they have done in their co-called native countries.

It is an astounding fact, accentuated and made obvious by this war, that scarcely any tropical countries have produced more than a few locally acclimatized descendents of the popular temperate vegetables, in spite of the numerous examples of the converse process of adapting tropical and sub-tropical crops to temperate climates. We should not be satisfied until we are able to grow to perfection strains of all the important kinds, at almost all altitudes and under almost all conceivable climatic and soil conditions. We must not be content merely to produce a "satisfactory" crop or two halfway up Mt. Elgon or Kilimanjaro. The bulk of the population lives in much hotter climates than these, especially in countries less favoured than Kenya. We must select, acclimatize and breed systematically, with this fact in mind. Such work would call for consistent and organized effort by, or under the guidance of, the Agricultural Departments. Such a scheme would pay handsome dividends within the first few years, as was the case when Kenya bred new strains of wheat, and I venture to suggest that it would be a big step in obviating famines.

6—Degeneracy and Reversion

The commonly held opinion that temperate plants *invariably* degenerate or revert when grown in the tropics, often to the extent of completely "fading-out" within three or four years, is an interesting one. Firstly, such statements are seldom supported with particulars as to what precautions, if any, were taken to isolate the plants from others of the same species (wild and cultivated), to prevent crossing. Secondly, details of roguing and selection are usually missing. It is, of course, known that a plant which is in an unhappy environment will not fully thrive and that if it and its descendents

are left to their own devices, the strain may die out; but its offspring will undoubtedly show some individual variations in adaptability and constitution, for a hundred and one known and unknown reasons. Should the best specimens be left among the common herd, they would (unless completely self-pollinating) soon lose their superior potentialities of adaptability and be dragged down to the level of the "failures".

Nature is continuously striving to return our garden varieties to their original state. Reversion, to nature, is not degeneracy. She abhors the monstrosities which adorn the tables of our horticultural shows. Wild plants are invariably more vigorous than their cultivated prototypes. The first few carrots of the season to throw up flower-heads, borne on exceptionally strong stems, should be more than suspect, for they would be an instance of Nature "getting away with it". Those plants are very probably reverting to the old thin, wiry "wild" root. The same often applies to the vanguard of the cabbage flowers, which usually emanate from the softest and most hollow hearts—at least one stage back to the open branching habit of the wild cabbage.

Paradoxically, the best seed, from the point of view of the market-crop grower and therefore of the seedsman, is obtained from the plants which have the most difficulty in producing seed. If it were not so, seed would be very cheap indeed, for the wilder the plant the more prolific it becomes.

7—Flower-Formation Assisted by Cultural Methods

(*a*) *Temperature.*—This has been dealt with in paragraph 2, but I may here add that a territory wishing to produce seeds of many kinds of vegetables must of necessity utilize the widest range of altitudes. Brassicas usually require very cold conditions to induce flowering. Kale appears to do well higher than anything else, up to some 10,000 feet, whilst tomatoes are too stunted at 7,000 feet but are very satisfactory below 6,000 feet.

(*b*) *Phosphatic fertilizers.*—It is not always necessary to supplement the natural phosphates in the soil, but an analysis should be made before deciding that additions are not required. For seed production, nearly double the normal requirements of phosphates should be available.

(*c*) *Lifting and Storage of Roots.*—Even under the best conditions so far experienced, roots do not mature or ripen in this country sufficiently to make long storage practicable. If the system of lifting the roots intended for subsequent seed production is followed, and they are stored for short periods, it will be found that the lifting (and consequent drying and damage to the roots and the tops) has had the effect of checking the flowering considerably. We have found that lifting is a necessary evil which allows us to select the best roots for retention, and that if carried out we should replant under irrigation. A compromise has been tried by us: digging a furrow alongside each row and examining the full length of only one side of the roots, thus leaving them almost undisturbed. It has proved very successful, but entails more work than lifting and replanting, and supervision of native labour must be redoubled, as there are no piles of sorted roots to be examined by the European in charge. Damage to the root does not appear to hasten flowering, but often causes root-rot.

(*d*) *Opening Hearts of Cabbage, Lettuce etc.*—The "book" tells us to cut a cross in the cabbage hearts when they are fully formed. This, in itself, is not enough. It is usually necessary to cut the cross right down to the stem (though not deeply into the heart) and wrench the tight mass of leaves apart with one's hands or with sticks. This operation may have to be repeated several times at intervals. The same applies to lettuce. In obstinate cases it has paid (in more than one sense) to cut off the head and allow flower-shoots freedom to emerge. If this system is adopted, all individuals unsuitable for reproduction should previously be uprooted and not merely cut down. Otherwise the vital evidence for roguing would be lost.

8—Harvesting

The period of flowering to seed ripening is very protracted with most of the vegetables grown by us in the Kenya Highlands. Probably after a few generations they will become more regular in their habits if selected to a uniform type. Mechanical harvesting is usually out of the question, as plants and even individual shoots ripen whilst their neighbours are only beginning to flower. This means hand-picking, which raises the costs considerably, also necessitating piecemeal cleaning and packing. Fortunately our exceedingly dry atmosphere obviates artificial methods of drying the seed-heads prior to threshing, which is done almost entirely by hand.

9—Cleaning and Grading Seed

It is an entirely fallacious belief of many farmers and gardeners that, should their seed not go through the cleaning and grading operation, and therefore contain some chaff and grit and some empty seed-coats, they may put this right by sowing more thickly and thus assuring a sufficient number of plants per acre. But the efficient cleaning of seed removes the menace of noxious weeds as well as the harmless adulterants such as chaff and grit. Grading, however, is far more important than cleaning, no matter how primitive the apparatus used. (We are using hand-sieves at present, because the cleaning and grading machine ordered from the United Kingdom has not yet reached us.)

Grading sorts the seed into its various sizes, shapes and specific weights. A large seed, plump and heavy and of typical varietal shape, has much greater potentialities of reproducing a plant as good as or better than, its parents, than has the light, undersized specimen. Its larger food store also gives it a better start after germination and allows it to survive if planted too deeply or during a dry spell. The grades of size and weight must, however, bear some relation to the conditions under which the seeds were formed, and must vary from season to season and field to field, for the amount of rain received and the type of soil in which the plants were grown will affect the size of the seed, although not impairing its inherent varietal characteristics. It is manifestly impossible for every small grower to possess his own grading machinery (in wartime, at least) so that apart from preliminary winnowing by the grower, the Seed Station has undertaken to complete the operation. It may be pointed out that the shape of the apertures for seed-grading screens are, ideally, about the same shape as the longer section of the seed (looked at edgewise), and not square, as are most of the wire meshes which are now obtainable. To grade, the seed must pass through one screen which is slightly bigger than the seed, and then pass over another screen with apertures a fraction smaller than the seed-size required for that grade. Hand-sieving, as carried out by us at present is, I am afraid, little more than glorified winnowing, and is not grading.

10—Seed Storage

It is not necessarily advisable to store seed in the locality where it happened to be produced. The driest atmosphere should be sought. If kept in a dry area, packed in double sacks and raised on battens for ventilation, and all rats and mice excluded, seed keeps in good condition for at least one year. The use of sealed tins presents dangers unless the seed is first thoroughly dried and allowed access to air (in sacks) to assure the "after-ripening" or maturation, which, with the majority of our vegetables, may take at least one month.

A chemical seed-dressing is desirable, and could best be applied during the cleaning process. If the chemicals are unobtainable, a dusting of pyrethrum powder will at least help to exclude insect pests. We have not yet observed either pests or fungus diseases on seeds stored at Turi. Labelling is very important, and it is advised to place an additional tag inside the bag, stating kind and variety, as the external labels frequently become detached during transport.

11—Field Trials

All seeds which pass through our hands undergo both laboratory and field tests. Germination tests are done at the Scott Agricultural Laboratories, Nairobi, and the field trials on irrigated nurseries at various altitudes. Before the seed is passed for redistribution the following are recorded:—

1. Serial No.
2. Kind.
3. Variety.
4. Grower.
5. Date sown.
6. Plot No.
7. Special condition of seed or soil.
8. Date germinated.
9. Germination good, fair or poor?
10. Apparent reasons if poor.
11. Laboratory test result.
12. Date vegetatively mature.
13. Flower initials premature?
14. Crop is good, fair or poor?
15. Additional observations.
16. Final recommendation.

12—Some Promising Varieties

We are not yet in a position to compile a comprehensive list of varieties and their best localities and altitudes, but we can name a few which have so far flourished vegetatively and also produced seed:—

Beans.—Most varieties. Arusha and similar districts.

Beet.—Blood Red Globe, Early Wonder, Egyptian. Best at 7-9,000 ft. Known to seed at Kampala.

Cabbage.—Ellam's Early, Early Jersey Wakefield, Winningstadt, Savoys and Drumheads. Cape Spitzkohl seeds well, but pure strains appear to be unobtainable now. Best from 7,000–10,000 ft. for seeding.

Carrot.—Chantenay is excellent vegetatively and seeds well between 7,500 and 8,500 ft., lower if short rains or irrigation, but if higher, are very slow and develop dwarfed tops. Early Market, Nantes and Oxheart are also successful at same levels.

Cauliflower.—The Patnas are well known to succeed at lower levels, but usually find it too cold above 6,000 ft. Southern Cross has so far proved our best for seeding, at just over 8,000 ft., at approximately 300 lb. per acre. Early Italian Giant and Snowball also do well, at about 7,500 ft., but they must have water at or just before flowering. That applies to all the cauliflowers.

Kale.—We are not considering this an important crop at present, but it may be of academic interest to record the fact that we have got it to flower and set seed (mostly eaten off by aphids) at altitudes between 6,500 and 10,000 ft.

Leek.—Early Giant. 6-8,000 ft.

Lettuce.—New York Special is so far the best by a long way, at 7-8,000 ft. An excellent heart for market, will stand travelling, and is now busy seeding. (A very tiresome crop to harvest and to thresh, lettuce.) Carter's All-the-Year-Round and Iceberg do well.

Onion.—Early Cape Flat and Hunter's River. Others would also do well up to about 8,0C0 ft., but we are relying almost entirely on the Bombay type which is produced at Moshi.

Radish.—French Breakfast, Scarlet Turnip and Crimson Giant seed profusely at 6,500 to 8,000 ft. As with all the pod-bearers, birds are a nuisance.

Tomato.—Apparently all United Kingdom glasshouse varieties and their equivalents from other countries romp away, especially between about 4,000 and 6,500 ft.

Turnip.—Purple Top White Globe and Early Snowball. Difficulty in flowering below about 7,000 ft., but encouraged by timely applications of water. Probably better for seeding at over 8,000 ft.

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THE VOCABULARY OF DENUNCIATION

The insertion of an unusual, well-sounding, expressive word in correspondence can often achieve much that would otherwise not materialize, by acting on the memory like the sand in an oyster which gives rise to a pearl. For example, I found "vicissitudes" on the first line of a letter—*le mot juste* which took my fancy as "changes of fortune" would not have done—and because the word stuck, sympathies were aroused which might otherwise have lain dormant.

But there is a danger in conscious search for effect, if it leads to slang. The "talkies" and the cheaper magazines have familiarized us with many words used by uneducated Americans, words which do not lack virility but which by their absence from dictionaries may lack exact definition. I have just seen an opinion of mine described in correspondence as "boloney". I presume the writer wished to express an honest doubt, but the dictionary does not help. We have already established in our own language many words which I think are far more effective than most of the American importations, and for those who wish to suggest adverse comment, backed by Webster and the O.E.D., I offer "borborygmus" and "sooterkin".

W.V.H.

THE CLIMATIC BACKGROUND TO THE PROBLEM OF POTATO VARIETIES FOR EAST AFRICA
Part II

By R. E. Moreau, East African Agricultural Research Institute, Amani

VI—Solanum tuberosum: *Relations to Temperature*

There is universal agreement that heat does not suit "our" potato plant. The famous British varieties have been developed in an area where the mean monthly maxima of their growing season vary between about 53°F. and 67°F., while no mean monthly temperature is higher than 60°F. It is the opinion of Salaman (1926) that probably a temperature of 80° or over in the shade will damage the growing crop. In Australia the view is held that "when the monthly mean rises above 75°F. potatoes no longer produce a profitable crop" (Bald, 1941); and, as we have seen, the Australian yield standard is low. In *Potato Growing in Mauritius* Coombes (1940) states: "The potato does best where the growing season temperatures range between 16° and 24°C. (61 and 75°F.), the maximum yield being produced under the cooler conditions". It is not clear whether this is the result of observations made locally and the whole statement lacks precision; by the coincidence of Coombes' upper limit with Bald's is interesting.

It has been stated that heat alters the whole habit of the plant. At Buitenzorg (Java) with a tropical climate having an annual mean of 78°F. and little daily (or annual) range, potatoes make long thin stems with small thin leaves and tubers averaging only ¼ oz. (Paravicini, 1923). These observations are in accord with the results of controlled experimentation. For example, Bushnell (1925) reported failure of tuberization on plants exposed to 79°-84°F. (and normal spring daylight). Nevertheless in Zanzibar, where the mean of the maxima is not below 84°F. in any month of the year, "fair" crops of tubers are occasionally obtained —though a high proportion of plantings are a total failure. In form the plants tend to be spindly and small-leaved but some "strongly resemble the normal at home" (Dept. Agric. Zanzibar, unpubl.).

In the U.S.A. "the potato has made its greatest development in the cooler sections of the country, where the mean temperature in July is not over 70°F. Further, the greatest yields of potatoes per acre are in those States where "the mean of the warmest month is not far from 65°F." Planting dates vary with latitude, February in northern Georgia, May in the States in the north, "when the seasonal rise has brought the temperature close to 45°F." (Smith, 1915, cit. Stuart, 1928). This temperature agrees closely with the mean for April in the Scottish Lowlands.

Investigations into the influence of air-temperature on tuber setting and development have been summarized by Werner (1934). The consensus of opinion at that date, that temperatures of 59°-64.5°F. (15-18°C.) are the most favourable, appears to have remained unaltered. It will be noticed that these temperatures are at least 5°F. above those ruling in the Scottish Lowlands, whence so many of the potato varieties planted in the tropics, at any rate of the Old World, are derived. This difference may not be a significant one: the British potatoes may not be closely adapted to the relatively low temperatures in which they have been developed. We simply do not know. Very little physiological investigation has been done on British-raised potatoes, doubtless because in the comparatively small, homogeneous area of the British Isles there has been little economic inducement. Werner's generalization "59–64°F." is, as his references show, based entirely on results obtained in the U.S.A., where, naturally, local potatoes were used. If, as is possible, they do stand heat better than British varieties, it might help to account for the importance of varieties derived from the U.S.A. in the Australian potato industry. Heat-tolerant potatoes have been produced in southern Europe: Mann (1921) found that in India all British varieties were outclassed by an Italian "which seems definitely

more resistant to heat and to the infection associated with a hot moist atmosphere". "Seed" from that source tried by the Kenya Department of Agriculture at Nyeri in 1940 and in 1942 gave, however, poorer yields than most varieties from Britain.

Soil temperature is a factor that must be borne in mind when potatoes are grown in hot climates. Cordner and Ward (1942), working in Oklahoma, have shown that soil at 90°F. causes physiological break-down of seed-pieces and that, apart from this, sprouting is affected. These authors do not mention the conclusion of Richards (1921) that young sprouts grow best in soil at 75°F. but that later growth is best in cooler soil, at about 64°. He remarks also that tubers, left in the ground after the haulms have died and so diminished the shade, may be damaged by "heat necrosis", especially in sandy soils.

VII—The Temperatures of the East African Potato-growing areas

Available temperature records are very few. To get an idea of the temperatures in which most of the East African potatoes are grown it seems best to use as a basis the temperatures of stations at the lower edge of the most important areas. It will follow that most of the potatoes are raised in climates cooler than those cited. Table 2 gives the figures for the most relevant stations. (The objections to using averages for temperature are not nearly so great as for rainfall, in tropical countries.) The months when the main crops are in the ground are indicated by black figures.

Altitudinally Kabete is about right to give the indication we want for Kenya; Tandala (from Heidke, 1910) is about 800 ft. above the altitude required for South Tanganyika and so 2-3°F. should be added to the temperatures given; Lyamungu is a little too low to give a fair indication for Kilimanjaro but only 1-2°F. can be deducted from the temperatures quoted; Lwandai (also from Heidke, 1910) may, from its situation, be if anything a little too hot to be typical of the lower edge of the main areas in Usambara. For Uganda it seems reasonable to take 5,500 ft. as the lower limit of the main potato areas, and to give an indication of the prevalent temperatures at that altitude the mean may be taken between those of Fort Portal (5,050 ft.) and those of Kabale (6,139 ft.). The temperatures given in the table for Northern Rhodesia have been averaged by the Department of Agriculture from the records available for the whole growing area Choma–Broken Hill.

The figures given in Table 2 for the main growing periods are, with the slight adjustments indicated, extracted to Tables 2A and 2B, where they are compared with data from the Scottish Lowlands. For this purpose records from Ruthwell, Dumfriesshire, practically at sea-level, are regarded as typical. The records from six other stations are found to be closely conformable.

From Tables 2A and 2B it is obvious that the temperatures at the lower edges of the main East African potato areas are above the temperatures in which the British varieties used were developed. As a consequence of the greater daily range at low latitudes the difference is greater between the relevant East African and British maxima than between the means. We do not know how closely the British varieties are adapted to their "home" temperatures and until physiological work is done on them it cannot be said whether East African potato-growing has already been pushed to altitudes so low that yield is seriously affected by the temperature factor alone. The mean temperatures ruling at the lower edges of the main potato areas in Kenya, on Kilimanjaro and in Usambara are, it will be noticed, in close agreement. If this is significant, South Tanganyika has a margin on the right side: but there is reason to suppose that in Northern Rhodesia potato-growing labours under a direct handicap. The mean temperatures there run 7°F. above those in Kenya and Tanganyika, while their mean maxima average 80°F., the temperature regarded by Salaman (1926) as actually harmful to growth as well as yield. Moreover, because all the Rhodesian areas along the railway are within a few hundred feet of 4,000 ft., this unfavourable conclusion applies to them without exception. The Rhodesian day-temperatures are, as it happens, very similar to those in the urban neighbourhoods of Uganda, where, as noted in section IV, the ready local markets are stimulating potato growing, though the yields are poor. At Kampala (4,300 ft.) the monthly mean temperatures vary between 68.9 and 73.9°F., the monthly mean maxima between 76.3 and 82.7 (average 79.3°F.).

In each of the Kenya and Tanganyika areas, potato-growing extends about 2,500 ft. above the lower edge for which figures are given in Table 2A and 2B. This altitude difference connotes, on a general average, a reduction of about 7°F. in temperature. Hence it may be inferred that in the highest Kenya and Tanganyika potato areas the main crops are subjected

TABLE 2

MONTHLY MEAN MAXIMUM TEMPERATURES

Station	Altitude	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	ft.												
Kabete	5,980	76·2	78·4	**77·5**	**74·3**	**71·9**	**70·0**	**68·9**	69·7	74·8	75·8	73·6	73·5
Tandala ..	6,800	70·1	**69·0**	**69·0**	**66·2**	**65·2**	**62·8**	63·6	67·0	71·0	76·2	75·2	71·6
Lyamungu ..	4,100	83·4	84·3	82·0	75·6	**71·3**	**69·9**	**69·4**	**70·7**	**75·1**	**78·7**	**81·0**	80·3
Lwandai ..	4,500	77·9	81·0	**82·2**	**76·8**	**74·4**	**72·6**	**72·2**	73·2	76·5	79·9	79·2	79·5
N. Rhodesia ..	*c.* 3,500	**79·0**	**79·0**	**80·0**	77·0	78·0	72·0	77·0	80·0	84·0	88·0	**83·0**	**80·0**
Uganda ..	*c.* 5,500	78·8	79·0	77·2	77·6	76·2	76·7	76·6	77·0	77·0	76·4	76·3	76·2
MONTHLY MEAN TEMPERATURES													
Kabete	5,980	65·1	66·9	**67·2**	**66·0**	**64·0**	**61·6**	**60·3**	60·6	63·7	65·3	65·0	64·3
Tandala ..	6,800	61·5	**60·4**	**60·4**	**59·4**	**56·7**	**52·8**	53·5	55·3	59·2	63·5	64·3	62·8
Lwandai ..	4,500	67·5	67·0	**68·0**	**65·8**	**64·0**	**61·5**	**60·8**	60·3	60·8	63·0	65·3	67·5
Lyamungu ..	4,100	70·9	71·2	71·0	68·2	**65·6**	**63·3**	**62·5**	**63·0**	**65·3**	**67·4**	**69·6**	69·6
N. Rhodesia ..	*c.* 3,500	**71·0**	**70·0**	**70·0**	66·5	66·0	61·0	64·0	68·0	72·0	76·5	**73·5**	**71·5**
Uganda ..	*c.* 5,500	64·9	65·7	65·0	65·4	65·0	64·0	63·8	65·0	65·0	64·8	64·7	64·2

The main crop periods are shown in black figures.

TABLE 2A

MONTHLY MEAN MAXIMA FOR GROWING PERIODS AT LOWER EDGES OF MAIN POTATO AREAS

Uganda..	77·2	77·6	76·2	76·7	—	—	—	Mean	76·7
Kenya	77·5	74·3	71·9	70·0	68·9	—	—	,,	72·5
South Tanganyika	71·0	71·0	68·2	67·2	64·8	—	—	,,	68·4
Kilimanjaro	72·3	70·0	70·4	71·7	76·1	79·7	—	,,	72·3
Usambara	82·2	76·8	74·4	72·6	72·2	—	—	,,	75·6
N. Rhodesia	83·0	80·0	79·0	79·0	80·0	—	—	,,	80·0
Scottish Lowlands	52·9	59·8	64·7	67·2	66·0	62·0	55·3	,,	61·1

TABLE 2B

MONTHLY MEAN TEMPERATURES FOR GROWING PERIODS

Uganda..	65·0	65·4	65·0	64·0	—	—	—	Mean	64·9
Kenya	67·2	66·0	64·0	61·6	60·3	—	—	,,	63·8
South Tanganyika	62·4	62·4	61·4	58·7	54·8	—	—	,,	59·8
Kilimanjaro	64·6	62·3	61·5	62·0	64·3	66·4	—	,,	63·6
Usambara	68·0	65·8	64·0	61·5	60·8	—	—	,,	64·0
N. Rhodesia	73·5	71·5	71·0	70·0	70·0	—	—	,,	71·2
Scottish Lowlands	44·7	50·9	55·7	59·0	58·1	53·7	47·9	,,	52·9

to temperatures only a little (2°-3°F.) above the British, and in South Tanganyika practically not above the British temperatures at all.

If now we consider the means in Table 2B in conjunction with what are regarded as the optima by American workers, viz. 59-64.5°F., we find that, with the exception of Northern Rhodesia, the East African means fall within this range. That is, the lower edge of East African potato-growing has apparently not been pushed beyond what are regarded as optimum temperatures in the U.S.A.

The foregoing conclusions relate, it will be noted, to the main cropping seasons in the East African areas quoted. So far as Kenya is concerned they would be less favourable for the subsidiary cropping season, between October and March, because the temperatures then are appreciably higher.

It will be realized that the temperatures on which the foregoing comparisons are made are all from records obtained in the "standard" way, that is in a screen about 4 ft. above the ground. It is likely that from the point of view of potato-growing these "standard" temperatures provide comparisons unduly favourable to East Africa. For one thing, the physiological importance of the higher East African maxima is not to be gauged merely by the temperatures attained. As Walter (1937, 1938) has repeatedly stressed, the importance of daily range to crop-plants lies not so much in its amplitude as in the summation of degree-hours above (or below) a critical temperature for the plant concerned. Thus interpreted, the divergence between British and East African maxima is greater than appears from Table 2A.

The effect of eco-climatic modifications of the standard climate must also be borne in

mind. Practically everywhere during the day air-temperatures increase as the ground is approached. Kirkpatrick (1935) found that at Kiambu (Kenya *c.* 5,700 ft. a.s.l.) on sunny days the temperature at 2 cm. (.8 in.) above the ground ran 8°C., i.e. over 14°F., higher than the "standard". Presumably because of the more intense radiation, this eco-climatic difference appears to be more marked in East Africa than at higher latitudes (cf. data given by Geiger, 1927). The difference, decreasing as the surface of the ground is left behind, is of most potential importance to the potato plant in its youngest stages and progressively less thereafter.

It is unfortunate that potato-growing in Java, which otherwise would provide instructive comparisons, appears to be so badly documented. However, it has been stated (Paravicini, 1923) that it is confined to altitudes of 2,600/3,300 ft. to 5,500 ft. in East Java and up to 7,200 ft. in West Java. Lembang, a "great" potato area, is at 4,600 ft. with an annual mean of 67°F. and monthly mean maxima varying between 76° and 80°F. According to Ochse (1931), although in the East Indies potatoes grow best above 3,300 ft. they "thrive already" at 1,700 ft—where no mean monthly maximum is below 85°F. nor monthly mean below 74°F. If these statements are critical and yields are reasonable it would seem that the potato varieties grown in Java stand heat better than those grown in East Africa. A subject for further inquiry when Java reverts to civilized control.

Soil temperatures

In this connexion, soil temperatures also are of potential importance. The critical temperatures will obviously be those within about 8 inches of the surface and during the first few weeks of the plants' growth, when the tender shoot is pushing through the topmost (hottest) layers of the soil and has not developed leaves enough to throw any shade. Table 3 shows the mean monthly temperatures (°F.) recorded by the B.E.A.M.S. at Kabete at various depths in the soil at the afternoon hours 14.30 and 18.00 of the planting months.

TABLE 3

Months	Depth					
	5 cm. (2 in.)		10 cm. (4 in.)		20 cm. (8 in.)	
	14.30	*18.00*	*14.30*	*18.00*	*14.30*	*18·00*
March	77·7	79·5	74·0	76·9	72·3	73·7
April	76·3	77·8	73·9	75·9	72·9	73·7
October	79·0	81·0	76·0	78·5	74·0	75·2
November	75·9	76·7	73·1	75·0	72·0	72·9

At night the soil, when dry, cools at two inches as much as 20°F. below the day maximum. At greater depths it cools less.

In records made at Kiambu (at about the same altitude as Kabete) in September, a month on the whole cooler than October, 95°F. was reached at a depth of 2 inches, 90° at 4 inches, on several afternoons (communicated by B.E.A.M.S.).

At Kampala soil-temperatures taken by the Department of Agriculture in clean-weeded ground for two years give fortnightly average maxima at 2 inches varying between 72° and 92°F., at 4 inches between 71° and 87°, and at 6 inches between 69° and 82°.

Records in unshaded soil at Lyamungu (Kilimanjaro, 4,100 ft.), communicated by the Chief Scientific Officer, give comparable results. At 5 inches down the monthly mean maxima at 15.00 hours—probably about the hottest time of the day—vary between 68°F. in July and August and 88° in December, January and February. At 10 inches down the temperatures attained are about 5°F. lower. In the first months the main crop is in the ground, namely May and June, the mean maxima attained at 5 inches are 70°–73°F., and in November and December, the corresponding periods for the subsidiary crop, 78–88°F. (two years).

The above figures must be considered in conjunction with the probability that soil temperatures do not fall rapidly with altitude and with Richards' finding that the soil temperature for the best growth is 64°F. If this is confirmed for varieties other than the single one he worked with, then most of the potatoes in East Africa are grown in soil that is too warm.

VIII—East African Temperatures in Relation to the S. andigenum *Group*

The foregoing paragraphs show that, although we do not know for certain, we probably have in most of the East African potato areas, except the highest, climates that are in some respects too hot for the best performance of the British varieties used. We may now consider the possibilities of the *S. andigenum* group in this connexion. Since the Andean and East African areas concerned are both tropical, differential daily ranges and eco-climatic effects need not be taken into account.

Because the lower edge of the "indigenous", thoroughly healthy, *S. andigenum* area is at 9,000 ft., as high as the upper edge of the highest East African potato areas, it will, at the outset, be suspected that the species of the *S. andigenum* group are native to a climate cooler

than any available for potato-growing in East Africa. This is confirmed by comparing the Andean temperatures quoted in section III with those arrived at in Tables 2A and 2B. Moreover it appears that although the *S. andigenum* group may be accustomed to rather higher maxima than British varieties of *S. tuberosum*, their native mean temperature is much the same, and on the whole any difference is so small as to be of doubtful significance for our purpose.

S. phureja is exceptional in the *S. andigenum* group for its low optimum altitude and its native climate must therefore be a little warmer. (Unfortunately the literature makes no attempt to define the lower edge of its successful cultivation.) The temperatures arrived at in section III for its optima are within those offered by the higher parts of all the present East African potato areas (except Northern Rhodesia), though they are below the temperatures ruling at the lower edges everywhere except in South Tanganyika. Consequently, on temperature adaption alone *S. phureja* might, unless it proves unusually sensitive to heat, contribute somewhat to extend potato-growing to the warmer parts of East Africa. There is no reason to suppose that the rest of the *S. andigenum* group would do so.

IX—S. tuberosum *and Length of Day*

Very definite opinions have been expressed that the potatoes of commerce are long-day plants. For example, Bald (1941) writes that commercial potatoes "produce a full crop . . . where they receive more than 13 hours full daylight each day. Many will produce . . . 50 to 75 per cent yield under short-day conditions, but never their maximum crop". Even more emphatic statements have been made by Driver (1941). "It has always been difficult, if not impossible, to grow potatoes in tropical countries. This is due to the fact that potatoes have been bred for and become adapted to the light conditions of the temperate regions and form tubers only when the daylight period reaches a certain minimum. In tropical regions the daylight period does not exceed twelve hours, and this is insufficient to initiate tuber development." Because day-length is one invincible circumstance of tropical agriculture and because the question is fundamental to a policy of potato selection for the tropics, the evidence for such statements as the foregoing needs close examination. It is of course obvious at the outset to anyone who has seen a Kenya potato that the last part of Driver's statement is exaggerated to the point of being entirely incorrect.

The history of the European potato stock, discussed in section II, is relevant in this connexion. If the view that they came predominantly from Chile is correct, then in their ancestry as well as in their adaptations to north-west Europe, the potato varieties that have been planted in East Africa might be expected to be long-day plants. But if it is true that the original potatoes and also those of 1851 came into Europe from the Andean dispersal centre, then their adaptation was presumably to short-day. *Ex hypothesi* a short-day adaption would have been among the characters "selected out" of them during their sojourn in north-west Europe: but it appears from recent experimental work (Imp. Bur. Plant Genet. *in litt.*) that early varieties are to some extent long-day plants.*

In any case it appears to be true that the importance of short daylight in affecting yield at low latitudes is much more of an open question than would be gathered from the statements quoted at the beginning of this section. Elsewhere (Moreau, in press) I have reviewed the experimental work on this subject.† Much of it proves on critical examination to be, for various reasons, inconclusive or unacceptable: some results, by different workers, are in direct conflict. Moreover, as it happens, practically none of the experiments have been done with the standard British varieties that have been used so widely for tropical planting. One is forced to the conclusion that the published physiological work provides no sound basis for the sweeping assertions that have been made about the depressing effect of short-day on yield. Before we accept that short-day, by itself, imposes a low ceiling on potato yields in tropical countries there is great need of experiments, using the varieties we are interested in and carefully planned to ascertain how differences in light intensity and temperature affect the reactions of the potato plant to shorter periods of daylight than they get in the European summer.

Turning to the field evidence, it is true that the general average yields for low-latitude countries are deplorably low, but, as shown in section V, many factors, some under the

* A bulletin on this subject is in preparation by the Bureau.

† For the convenience of those interested the references are included in the bibliography of the present paper.

growers' control and some not, contribute to this result. Certainly from these average yields it is impossible to assess the influence of short daylight or, indeed, to establish that it has any influence at all.

One fact, fully established experimentally, is that under short days the maturity period of any given variety is reduced. Making all allowances for the effect diseases have on haulm and the consequent fallacious early appearance of maturity, there is no doubt that the experimental findings in this respect have been confirmed by field observations everywhere at low latitudes. On collating all the well-documented evidence available I have found that in the African countries and in Java, Hawaii and Fiji, the maturity period of potatoes is reduced from 25 to 50 per cent below that of the variety concerned when grown in northern Europe. The reduction in the total number of daylight hours received by the plant is astonishing. Late varieties—which include Kerr's Pink and Up-to-Date, the mainstays of production in East Africa and South Africa respectively—get about 2,600 hours of daylight in the Scottish Lowlands, but only about 1,450 in Kenya, 1,625 when grown as a summer crop in South Africa, 1,320 when grown there (irrigated) in the winter. In the face of these facts it is very noteworthy indeed that yields that are, on any standards, excellent, have been obtained, not merely on experimental plots or in gardens, but on a commercial scale in Kenya (8 tons to the acre), in Southern Rhodesia (6.7 tons to 12.5 and 13.4), and in South Africa (10 tons and more). These figures show what can be achieved at low latitudes when the crop receives something like the treatment—above all the heavy manuring—regarded in Europe as its due*. They show moreover, conclusively that reduction in yield is not necessarily commensurate with reduction in light ration.

The inference is that either the potato plant does not react to reduced light as has been believed or there is some countervailing influence in the tropics. It is possible that this may be found in the increased light-intensity near the Equator: in Kenya "the actinic properties of the 12-hour day are greatly in excess of the 18 hours of higher latitudes" (A. Walter *in litt.*). Another, minor, influence favourable to yield might be the relative paucity of flowers and absence of (true) seed in the tropics as a result of both greater heat and shorter light (Salaman, 1926, p. 181; Werner, 1934, p. 29). Bartholdi (1942) has demonstrated that flowers and seeds on a plant depress its tuber formation significantly—though his results are at variance with some earlier ones. Seed formation in East Africa certainly appears to be extremely rare.

Reducing the light ration has a subsidiary effect that the tropical grower may be able to turn to his advantage. Werner (1934) found in his experiments that "increasing length of day was the most efficient means of increasing the length of the primary stolon". In other words, the shorter the day the more compact the subterranean growth. Subsequently Coombes (1940) has remarked, apparently as a result of observations in Mauritius, that "in the tropics the tubers are usually produced in a bunch at the foot of the plant". This feature is certainly most noticeable in plants that I have seen at Amani. It appears then that where tropical growers can supply enough water and plant-food they would be able to adopt a closer spacing than is usual for the same variety in Europe. The great potential importance of this is indicated by the fact that on a spacing of 15 inches by 12, no more than 12 oz. of tubers per plant are needed to give a yield of 11 tons per acre. Incidentally, the excellent Rhodesian yields quoted above are obtained with spacing almost the same as, but slightly closer than, the standard for late potatoes in the U.K.

X—The S. andigenum *Group and Length of Day*

The reactions of various species of this group are being studied experimentally at Cambridge (Hawkes, 1941). Pending publication of the results it may be pointed out that the existing information about these species cannot be taken literally.

It has been stated (Anon., 1936, p. 5) that "the Andean potatoes . . . are all typical short-day forms and only produce a crop of tubers when grown under conditions of reduced length of day, the illumination being reduced to 9 or 10 hours daily". If this were true the Andean potatoes would certainly be ill-adapted for East Africa, since in Kenya no sunrise-to-sunset period is shorter than 12 hours and even in South Nyasaland it is at no season shorter than 11 hours. In fact, however, the 9-10 hour periods specified cannot be reconciled with those ruling in the Andean home of the *S. andigenum* group. Round Lake Titicaca, at about

* It will be noticed that by comparison the yields obtained in the Kenya plot experiments (quoted in section V) make a poor showing. But, apart from other possibilities, the climate at the low altitude where the work was done may have been against yield.

15°S., where the potatoes are grown in the southern summer (Hawkes, 1941), the duration of daylight varies between 11½ hours and just over 13 hours. And nearer the Equator the day approximates of course, more nearly to the perennial 12-hour day of Kenya. Even if the potato areas are mountainous the plots cannot on the average be so shut in that their day-length is shortened by 2½-4 hours.

Experiments have been reported from India where 15 of the "new" Andean species were subjected to a constant 9 hours daylight (*Ann. Rep. Potato Breeding Scheme Northern India,* 1939-40, 1940-41, 1941-42). The finding is that while the short day "exerts an extremely depressing effect on flowering in all species", in most of them it produces yields higher than in plants exposed to the local daylight (at Simla, 31°N.). "Vigour was, however, greatly reduced" and in any case only small tuber yields (not specified) were obtained. it was later found for most species that for a combination of vigour and yield long-day was needed from germination to the start of tuberization, short-day for tuberization. To the foregoing conclusions *S. andigenum, S. leptostigma, S. rybinii* (and *S. tuberosum*) were exceptions. These set more tubers under the natural daylight, i.e. rising to about 14 hours a day.

It is unfortunate that this experiment was planned with such excessively short light-periods as 9 hours, encountered in no potato area in the world during the growing season. Moreover it would be helpful to know the temperatures to which the plants in the greenhouse were exposed, since they may affect the reactions to light. The mean monthly temperatures in the open at Simla vary during the growing season of the potatoes between 55.7 and 68.8°F. (*ibid.*). It may therefore be suspected that in the greenhouses the temperatures were above the optimum for the Andean species and might conceivably have affected their reactions to light.

XI—Discussion

We are now in a position to consider the two authoritative opinions that form the text of this inquiry:—

(1) That *Solanum tuberosum* can never be expected to give more than a 50 per cent or 75 per cent yield in the tropics because of the short day.

(2) That the salvation and extension of potato-growing in the tropics can be looked for in the newly discovered Andean species.

From section IX it appears that for tropical potato-growing the presumed long-day adaptation of *Solanum tuberosum* is a bogey without practical effect. It has not been shown conclusively by experiment that short-day reduces yield under any conditions comparable with those in East Africa. On the other hand yields that are excellent by any standards are undoubtedly obtained in Tropical Africa with potato plants receiving a far shorter period of light than they would in the U.K. The generally low yields at low latitudes must be due to other causes, of which many are present. A grower in Europe who "did" his potatoes as badly as most tropical growers "do" theirs would not expect good yields.

Turning to temperatures, we have seen (section 7) that at the lower edge of the main East African potato areas the plants have to put up with much greater heat than they would experience where the varieties used were developed. In the higher parts of the East African potato areas certainly the mean air temperatures are not much above those of the Scottish Lowlands in summer, but in East Africa the disproportionately high daily maxima, the high soil temperatures and the eco-climatic effects combine to make the climate to which the potato plants are subjected effectively much hotter than the "standard" air means would indicate.

The effects of heat on yield in British varieties have never been properly investigated. Such indications as there are suggest that most of the East African crops are raised in temperatures not conducive to good yields. This applies above all to Northern Rhodesia, where potatoes are grown in the face of heat disadvantages *ex hypothesi* greater than in other East African territories.

If any long-day adaptation *S. tuberosum* may possess does not, under tropical conditions, operate to reduce its yield, then one of the theoretical reasons for turning to the *S. andigenum* group for East African cultivation disappears. Another goes when we realize that with a single exception potato species of this group cannot be expected to like East African temperatures any better than British varieties of *S. tuberosum.*

As regards rainfall, the moderate amounts received during the growing periods in most of the East African potato areas should accord well with the rather austere conditions of the *S. andigenum* crop in the Andes and it would not be surprising if some of the new species, especially one or two that are regarded as drought-resistant, could be grown satisfactorily on lower rainfalls than those indicated in section IV as apparently necessary for *S. tuberosum* in East Africa. On the other hand the

wet areas on the south face of Kilimanjaro and in parts of Southern Tanganyika might be unsuitable for potatoes of the *S. andigenum* group. Nothing definite seems to have been recorded about the yield of any of the *S. andigenum* group under any conditions.

Reviewing the foregoing paragraphs, it appears that on climatic grounds alone there is no reason to believe that anything would be gained by trying to introduce members of the *S. andigenum* group to replace *S. tuberosum*. For breeding for disease resistance the case may well be stronger, but it should be recognized that most of East Africa is probably climatically unfavourable and the best chance of raising breeding stock is in the coolest localities that can be found without frost. (Although frost-resistance is claimed in the *S. andigenum* group this may depend upon the air being dry.)

Finally, it may be worth recalling that for an economic utilization of a potato crop keeping-quality may be no less important than yield; and in this respect tropical, and low-latitude, countries generally have a special problem. Trials in Kenya have illustrated how a good-cropping variety may fail as a "keeper" and *vice versa* (Morrison, 1935). Special attention is being given to this problem by breeders in India (Pal, 1940). The keeping qualities of the "new" Andean potatoes do not seem to have received consideration, but short dormancy is a character of several species.

From the somewhat depreciatory and cautionary assessment of the *S. andigenum* group made above, one member, *S. phureja*, must be excepted, to some degree on climatic grounds, but much more because of its intrinsic food-value. The original report was that this species "is found normally in hot valleys and is one of the few potatoes in which tuber formation is not impeded by humid, hot, subtropical conditions", so that on the basis of this species "a great extension of potato cultivation in tropical and sub-tropical countries may be foreseen" (Anon., 1936). The report on the British collecting expedition (Hawkes, 1941) has since shown that the optimum of *S. phureja* is at about 8,000 ft. in the Andes. On this basis temperature comparisons indicate that it might stand heat slightly better than British *S. tuberosum* and to that extent increase the area under potato cultivation within the tropics, but the advantage of this species on grounds of temperature adaption alone is not likely to be great. Dietetically it would be an especially valuable acquisition because of its high protein content. About its yield and its keeping qualities nothing seems to be on record. Its dormancy is said to be short.

Whatever efforts are made to introduce the *S. andigenum* group as producers or for breeding, it is evident, especially from the slow progress with the "new" Andean species at the Simla potato station, that *S. tuberosum* must be relied on for the potato crop for a number of years to come. If trials of varieties are pursued it might be worth while not to concentrate on British varieties so exclusively as hitherto. United States varieties developed in hotter climates than the British might do well here (though the famous Katahdin has been disappointing in South Africa).

Also it is most desirable that something more definite should be learned about the physiology of *S. tuberosum*, a plant both actually and potentially so important a food-producer. Investigations, using outstanding British varieties, might be planned to elucidate:—

(i) Photo-synthetic relations to light of different intensities, up to that of tropical sunlight.

(ii) The relation of tuber formation and yield to daylight—

(*a*) of various fixed durations,

(*b*) progressively changing, as in the temperate zones.

(iii) The effect on yield of air temperatures, both night and day, the latter especially above 68°F. This would be linked with a study of respiration rates in relation to temperature.

(iv) The effect of air temperature on response to different light rations and intensities.

(v) The effect of soil temperature on yield.

Such knowledge, no less than the good husbandry the crop deserves, is a necessary basis for extensive and satisfactory potato-growing in East Africa: but it must be realized that because the potato is a difficult "subject" and because yield is affected by such a multiplicity of factors, conclusive results from experimental work cannot be expected to come easily or rapidly.

XII—Summary

The climates and seasons of the East African areas in which potatoes (*Solanum tuberosum*) are grown are reviewed with reference to:—

(*a*) The generally accepted climatic preferences of *S. tuberosum*, in rainfall, temperature and length of day.

(*b*) The suggestion that species of the newly discovered *S. andigenum* group can be used to extend potato cultivation in the tropics.

The conclusion is reached that, given good husbandry, excellent crops of *S. tuberosum* can be raised in parts of tropical Africa, even though air and soil temperatures seem unfavourably high. The short days seem to be of no practical importance. On purely climatic grounds there is no reason to suppose that potatoes of the *S. andigenum* group would do any better than the present U.K. varieties of *S. tuberosum*. In fact, most of them might be more sensitive to heat. *S. phureja* is an exception, and moreover a species especially desirable because of its high protein content.

Meanwhile, dependence on *S. tuberosum* being inevitable for the present, physiological investigation of the varieties used is very desirable: and U.S. varieties, possibly better adapted to heat, might be worth trying.

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POSTCRIPT

Since the above paper was completed many efforts have been made to obtain particulars of yields of potatoes obtained on a commercial scale by European growers in Kenya but without success except in a single instance. We are indebted to Mr. Eliot Crawley for giving full information about his potato-growing experience at Turi, at altitudes of 8,200–8,500 ft. above sea level. He finds "very definitely" that potatoes planted March-April give a better yield than those planted later, say, August-September, though the former are much more susceptible to disease. His potatoes take four to five months to mature. He has dropped Kerr's Pink completely owing to their contracting disease so readily. An unidentified variety known as "English White" gave 64 bags (5 tons) to the acre in 1943, even though struck with Irish Blight. The best yield he has ever had is 120 bags to the acre (over 9 tons) from unnamed native-grown potatoes planted in 1941 on six acres of land that had been enriched by having had squatters' goats and sheep living on it for a number of years.

This excellent yield is in the same class as Mr. J. K. Hill's over 8 tons to the acre, also at a relatively high altitude with temperatures comparable to the British. It is a further, valuable, illustration of what can be obtained, on manured land, with a far shorter total period of light than potatoes get in Europe. A yield of over 9 tons to the acre is above the average of even Lincolnshire and moreover it was obtained with "native" seed. R.E.M.

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CARE AND MANAGEMENT OF WORKING OXEN

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In this article I have to acknowledge gratefully the advice of E. H. de Waal, Esq., J.P., Chairman of the Elgeyo Border Production Sub-committee, Eldoret.

One hopes it will be long before the working ox disappears from Africa. He is useful for so many jobs on the farm which would be costly if done by mechanical transport. His food is cheap and his very presence on the land helps its fertility. If the waste products of the farm are collected he will tread them into farmyard manure or prepare them for composting: It has been claimed that, with the aid of one ox, as much as 12 tons of compost can be made every year under suitable conditions.

In Africa the farmer cannot always see to everything that is going on every day. He may be ill or away on business and on a large mixed farm he is frequently overworked. It is under these conditions that it is useful to have a few teams of oxen. If they are well trained and are not overloaded they will do good work for days at a time with very little supervision. The farmer is less worried when he has to miss inspecting his teams at work than when he has to neglect a tractor and, if he has trained his drivers properly, there is less loss and damage. A tractor is a grand implement when under constant and competent supervision, but it becomes a bottomless sink for the farmer's money if he cannot look after it properly.

This article is written round native oxen which stand up to East Africa's conditions of work better than grade cattle.

Class of Animals.—The class of animal required, particularly for dry country or country liable to long dry seasons, is a short, fairly small, big-boned, broad, compact beast. Such an ox will fill his belly in about 1½ hours during the midday outspan and thus have a period in which to lie down to rest. The big beast, particularly a grade, will still be hard at it gathering food when it is time to be inspanned again; he will soon knock up under continuous work unless the feed is very good.

When buying young animals care should be taken to avoid thin, narrow, leggy creatures.

Colour.—It is generally considered that black cattle are the hardiest, next comes the dark red, then the parti-coloured and dun and last of all the white.

The thickness of their hides also usually runs in the same order, the black having the thickest and the white the thinnest hides.

Feeding.—An ox should never be allowed to graze on very young grass or young volunteer wheat, oats, etc., as such feeds will cause them to scour and may cause hoven or Bloat, i.e. a blown-up condition which may be fatal. The working ox cannot pull on such food.

The lush young growth which follows veldt burning in the middle of the rains is reckoned by some people to be exceptionally dangerous and if there is no choice of feed between very old grass which has lost its nourishment and the very young stuff, then the animals should be made to fill their bellies with the old grass and be allowed only a few minutes on the very young stuff in the evening. The period on the young grass can be increased gradually.

In the dry season when the grazing is poor and there is no provision of hay or other nutritious fodder, the working ox should either have his work reduced, commensurate with the lack of feed, or he should be given concentrated feed to compensate for the lack of nourishment in the grazing. If very hard work is required of him he should get both good hay and concentrates when the grazing is poor.

The master's eye should inform him when extra feeding is needed. The working ox should not be fat but he should shine with health. Directly he loses this fine condition a little extra feed or less work is wanted.

The best time to judge the condition of a team is when they come up for work early in the morning, not at the end of a long hard day or when they have just blown themselves out with a good drink of water at midday!

Extra feeding should start early, before there is any danger of the animals falling off in condition and, in order to avoid digestive troubles, new feeds should be given in small quantities at first and be increased gradually. The usual grain given in East Africa is maize, either the grain kibbled fairly fine or as corn and cob meal, i.e. whole ears of maize ground up in a feed mill.

1 lb. kibbled maize at morning and evening or 1½ lb. corn and cob meal, mixed with chaffed hay or grass can be fed as a start, increasing up to a total of 6 lb. or 7 lb. daily per beast.

The hard woody maize cobs themselves ground up are not recommended, as the energy required to digest them just about equals their food value. They are useful as roughage mixed with concentrated food.

Sunflower-head meal is an excellent feed either alone or with grain.

All the common grains, native or European, can be fed but are better crushed or kibbled. Beans of the genus *Phaseolus* should not be fed raw as they sometimes contain hydro-cyanic acid, which disappears on cooking.

Hay should be sweet-smelling, not musty or damp. Well-made hay has a greenish colour. Depending on the grazing available, a working ox needs up to 20 lb. hay or dry fodder daily. Ordinary bush grass makes good hay if cut when in flower. Maize* and Napier grass stover are bulky feeds which, with some grain, will keep oxen in good condition through a long dry season when the grazing fails.

Feeds strange to native cattle, such as cabbage, kale, carrot and turnip-tops and edible canna tops, will be refused at first but if chopped up, mixed with kibbled maize and sprinkled with salt, the animals can soon be induced to eat them. Chaffed young sugar cane is an excellent feed and is a great help in getting stock to take less palatable or strange feeds when they are mixed with it.

Salt is an essential. A working ox needs about two-thirds of an ounce daily or 1¼ lb. a month. Some people have salt kept in front of their animals all the time, using blocks of rock salt or bricks of prepared lick under shelter from the rain. Others give their oxen salt only on Sundays, averring that if given on working days it spoils their working capacity. The supporters of this latter theory state that salt makes the beasts drink too much and loosens their bowels. Whichever method is followed the farmer is strongly advised to see that his own beasts, and not those of his squatters, get the salt. Many farmers swear by a well-known proprietary intestinal disinfectant which they mix with the salt and reckon it to have a tonic effect as well as being a preventive of internal disorders.

The feeding of sterilized bone flour with salt is strongly recommended. Few of the East African pastures contain enough phosphorus or lime. One simple method is to grind coarse salt to powder (it grinds easily if dried in the sun) and mix equal parts of salt and bone flour together. Another useful mixture is one part each of salt, bone flour and flocculated lime damped with water to make a stiff "dough" and then cast into moulds and dried on iron roofs. The bricks are a convenient form for placing licks in front of stock. Small additions of sulphur, iron and other salts can be made when necessary.

The new farmer should ask the advice of his nearest veterinary officer as to the minerals, if any, which should be added to the salt lick. Common additions are flocculated lime and sterilized bone flour, the latter is recommended as most pastures in East Africa are deficient in phosphates.

Watering.—Working oxen should be given the opportunity to drink three times a day; in the morning before inspanning, about noon and in the evening. Just any dirty water will not do. The cleaner the water the better the health of the stock. A water trough is the best way of watering cattle. The beasts should not have to crowd each other and fight to get to the water. Many watering places can be improved by paving with stone or concreting a runway into a stream or dam. Fencing is often needed to stop them going up-stream to foul the water for those who are drinking below.

If there is liver-fluke about, stock should not graze in vleis or marshy places until after the old dead grass is burnt off in the dry season. When the rains start again such places should be avoided. Watering from troughs is essential if fluke is on the farm. The water should be filtered through sand boxes and this will stop the beasts getting infected.

Hours of Grazing.—It is a well-known fact to those who have done long journeys with oxen that soon after midnight they will make a move; it may be only to get up and turn about so as to lie on their other side, but often it will be to graze for an hour or two if they are able. When on trek oxen will often try to walk home at this time and the herd boy should be warned to be careful that they do not stray.

As oxen usually like a feed during the night it is best to keep them in a paddock or to have a night herd. However, as reliable night herds are scarce, a good system is to have the oxen taken out to graze at 3 a.m., until it is time to water and inspan them. Some farmers put

* *See* "Feeding Values of Stover from Maize Millet and Bulrush Millet", M. H. French. *E.A. Agricultural Journal*, October, 1943, p. 88.

a *kengele* or gong out in the grazing ground to be struck by the herd at 3 a.m., as a sign to his master that he is doing his work. Under such a system it is necessary to have a day herd boy as well.

A suitable daily programme would be as follows:—

3 a.m. to 6 a.m. ..	.. 3 hours' grazing.
6 a.m. to 10.30 a.m.	.. 4½ hours' work.
10.30 a.m. to 2 p.m.	.. 3½ hours' grazing.
2 p.m. to 5 p.m. ..	.. 3 hours' work.
5 p.m. to 10 p.m.	.. 5 hours' grazing.
10. p.m. to 3 a.m.	.. 5 hours' rest in boma.

In practice the 11½ hours listed as grazing would, with going to and from work and the watering places, be reduced to about 9 hours. So long as there is plenty to eat oxen will do well, but if the grazing falls off, some extra feed should be given in the boma. Hay racks are advisable to prevent feed being trodden under.

When being moved to and from grazing or water, oxen should not be driven fast or be beaten by the herds: it is their period of rest and refreshment and the herd boys must be made to respect it.

If cattle have to be kept in a boma during the wet weather the farmer should seize this opportunity to get large masses of bedding thoroughly impregnated with water, dung and urine for composting. Mud does not worry native cattle who usually seem to pick on deep muddy places in which to sleep provided the climate is not very cold. A shed with one side open, away from the prevailing wind, is a help to stock in very wet cold weather.

Shade and Shelter.—In hot parts of the country, shade in the daytime is most valuable. If there are no trees a rough shelter should be put up.

In higher colder parts, even at midday, one can often see oxen who have finished grazing going off to long grass to lie down out of the cold wind. In this case low windbreaks and not sunshades are required.

Sickness.—When anything out of the ordinary run occurs the advice of a competent veterinarian should be sought.

The greatest preventive of sickness is the intelligent watchfulness of the farmer and his insistence on his drivers and herd boys adhering strictly to the regimen he lays down. The beginner should obtain good veterinary books such as Leeney's "Home Doctoring of Animals".

Careful study and an expenditure of a few shillings will save the new farmer many pounds.

If a beast dies of some unknown cause and the owner cannot do a post-mortem examination or get a veterinarian in time, the body should be burnt. This practice discourages natives from killing cattle in order to be given the meat. Moreover, burning a carcase may save the novice from contracting anthrax.

Whenever there is a serious illness, blood-slides should be sent to the nearest veterinary officer. The method is to prick the beast's ear, pick up a drop of blood with the end of one glass slide and make a very thin smear with it all over the other by drawing it from end to end. The smeared slide is dried by waving it in the air and packed carefully.

The following brief list of common troubles is included because most of them are caused by bad management or because deaths are often due to these common ailments being wrongly treated. In East Africa, where the nearest veterinary surgeon may be fifty miles away, the farmer will seldom have time to get expert opinion in urgent cases and will not be able to afford a special visit in minor ones; he must therefore be prepared to deal with every-day ills as a part of his normal work in caring for his oxen.

Bloat or Hoven.—When an ox is hot and tired he should never be given grain until he has had a drink, been grazed and rested. Tired, heated animals blow up very easily. Lush grass or green corn will also cause bloating.

To relieve this condition a pint of raw linseed oil mixed with a little turpentine or paraffin oil or ghee is given. Herd boys should be reminded regularly to report cases of bloating quickly, particularly when the rains start. Unless a dose can be given promptly the animal may not be saved without recourse to puncturing the rumen midway between hip-bone and last rib in the near (or left) side. This is done with a short stabbing instrument called a trocar which fits into a tube called a canula. A strong determined stab is needed and the trocar is slipped out, leaving the canula in position until the wind has finished escaping. It is best left in for half an hour, after which it may be withdrawn and the place smeared with a mild antiseptic.

Constipation.—This is often a symptom of some illness but may be due to very dry grass, lack of exercise or lack of water. To relieve it half a pint of raw linseed oil is given two

or three times in a day, followed by a change to greener food. Similar dosing can be done with Epsom salt at the rate of ¼lb. to a bottle of water or a mixture of half castor and half raw linseed oil.

Drenching.—As a drench going the wrong way often causes death, a description of the right way to give a bottle of medicine is offered.

The animal's head is held up so that the mouth is a little higher than the throat. A finger or thumb is inserted into the side of the mouth which is opened. Then, *first touching the roof of the mouth with the bottle,* pour fairly fast.

The neck of the ox should be kept straight. As he is able to swallow quite quickly, a pint can be poured down in one go. If the dose is bigger and he shows signs of wanting a rest or a breather he should be allowed it, but slow pouring and the giving of driblets should be avoided. A bottle with a long sloping neck is the best to use. (As horses and pigs cannot swallow fast these animals should be given liquid medicines very slowly.)

Sore Necks.—A common cause of sore necks is having the strop too long. It should be fairly tight, that is the reason why a skey is made with two notches, so that good fitting may be done. When the strop is slack there is too much up-and-down play in the yoke, which causes chafing.

Another cause of sore necks is the skeys being too far apart in the yoke; this gives rise to too much side-play on the neck. The strops when fastened should come down almost straight, following the line of the skeys.

Sore necks can be caused by working in dust and rain as well as by rough yokes. The latter trouble is easily prevented by sand-papering the rough places.

The cure for sore neck is to remove the cause (if possible) and to rub castor oil into the neck at night. In the dry season it is a sound precaution to do this to all oxen who show any signs of skin cracking. The oil should not be put on in the morning or during the day if it is dusty, as dust will collect on the oily place and aggravate the condition.

Abscesses.—Abscesses are often due to blows, pricks from thorns and horning.

The farmers should leave abscesses and swellings on bones to the veterinary surgeon as these often contain joint oil. Abscesses on soft parts of the animal can be lanced when they begin to "point". The best way to do this is to hold a sharp knife so that half an inch protrudes between thumb and finger and make a quick crescent-shaped cut. The abscess is syringed out with an antiseptic and the place plugged with tow soaked in any convenient germicide *mixed to the right strength.*

Carbolic oil or vaseline dabbed on an abscess helps to soften the skin and bring it to a head.

Prevention is better than cure, and if there is no cruelty to the oxen there will be fewer abscesses and kindred troubles.

Broken Horns.—If a horn gets broken off a pad of cotton-wool soaked in carbolic oil or warm carbolized vaseline should be bound over the stump and tar smeared well over it. This should be well covered with a strong bandage put on to stay on. The tar will protect the wound from flies: the great danger with this injury is maggots.

Snake-Bite.—The treatment is similar to that given to a human being. The place is cut and crystals of potassium permanganate bound on it. A tourniquet is put on for an hour but loosened every 20 minutes. As a rule one does not hear of the trouble until an hour or so has passed. I have treated two cases with apparent success (or at any rate without losing the beasts) by injecting a concentrated solution of potassium permanganate in boiled rainwater. Four places close to, and on the heart side of, the bite and one on the other were selected and about 2 or 3 cc. put into each place. Distilled water would be better than rainwater no doubt.

Medicines.—It is an advantage to keep two complete sets of emergency cattle medicines so that if the master or his foreman is away it will be possible for the drivers or herd boys to have access to a supply in case of trouble.

Inspanning Oxen

The oxherd will have brought the teams in a mob and halted them some little distance away, and the various little boys will be cutting out each his own oxen, possibly helped by the brake boy or plough boy if the cattle are fresh and inclined to frisk about.

When the team has been collected they are driven gently towards the driver who stands holding the reims—one for each animal. When they are close up he whistles or calls to them, and they stop in a line, shoulder to shoulder, facing him, each head ready to take the loop of the reim.

The driver then places the loop of the reim over each pair of horns and the boys lead the oxen to their places where they stand until the yokes are lifted and laid upon their necks and secured by the strops round the throat.

The whole operation should go on without noise, confusion or ill-treatment. The animals should stand about comfortably, chew the cud and look placid.

These pleasant conditions will not, of course, prevail on a new farm or when new oxen are being trained, but with firmness it should not be long before the routine is performed smoothly and quietly by men and beasts. Unless an atmosphere of good order and good temper is insisted upon by the farmer his cattle will not be able to do their best.

Drivers should be given not only firm orders and censure. Praise should be bestowed whenever possible, so as to encourage them to take a pride in their teams and work. An occasional small rise of pay or a present given judiciously will repay the farmer many times over.

General Rules for Inspanning Oxen.—A lead ox, once trained, should not be put into the rear nor a wheeler into the lead.

The best pullers should always be in the front 4 or 6 next to the leaders. This keeps the team (and the pull) straight.

The normal function of the wheelers is not to pull hard but to steer and to hold a vehicle going down hill. They should, of course, be good beasts, ready to pull hard when help is needed, but guiding and holding back the wagon when going down hill is as much as one should expect from them. The driver should not always be pushing the wheelers (or rear yoke of oxen in the case of an implement) to make them pull hard, they have all they can do to steer: in fact, the only steering gear that a wagon has, consists of the pole and the wheelers. A big ox and a small ox should not be yoked together; also each pair should be as nearly as possible of the same strength.

Oxen should be graded in size from front to rear; a small pair should not stand immediately in front or behind a big pair. If they do there will be too much downward pressure on the necks of the big beasts and a tendency to lift the yokes from off the necks of the small ones, with an attendant upward haul of the strops on their throats. The length of the ties can, of course, be altered to prevent this, but if a driver is incompetent enough to commit the one fault he is not likely to make any such adjustment.

If there are several teams on a farm the small oxen should be put together and if necessary 18 small oxen can make one team and 14 big fellows another.

When at work the driver should walk next to the wheelers or rear yoke so that he has the whole team in view and under control.

A *Mtoto* or *Mshika Kamba* to lead the oxen should be provided. It is necessary to accustom the lead oxen to follow someone. Much less damage to vehicles and implements occurs if there is an ox leader well under the control of the driver, as the leading oxen will then know with certainty where they are required to walk. This obviates the bad practice of drivers, brakeboys and others rushing at the leading oxen to flog them into the right path or round the correct turning. When the leading oxen do not know the way and are pushed about from side to side the momentum of the team falls off and if the track is bad the vehicle may stick.

Failure to supply a child to lead the oxen is not so serious when ploughing old land with a good team which can leave a really good furrow behind it, but no *vehicle* should go to work without one.

When breaking up new land a good ox leader can often save the team and gear a nasty jolt by spotting stumps, rocks or small anthills, which will bring the team to a sudden halt. The good ox leader will also save his master broken chains and implements and it is false economy not to have a *Mtoto* to each team.

Training Oxen

The training of young oxen may begin at 2½ to 3 years of age. It can be started at the earlier age if they are to be well cared for, i.e. given short hours of light work, good food and no heavy beating. If a young ox is overworked he takes a long time to pick up again and will not grow into a good beast. Kind and sensible training should be the rule.

When strange oxen are brought onto a farm for training it is best to wait until they have settled down to the new conditions before beginning to train them. A couple of weeks should be long enough.

If untrained oxen are herded with the workers they soon get accustomed to the routine and become familiar with the sight and sound of trek gear and of the others being inspanned. This helps to make them less fearful when their turn comes.

When training is started it should be under the best driver on the farm and it will

frequently happen that a young ox who is used to being handled will walk off quitely with the team and start his career without trouble.

The young ox should be inspanned with a quiet animal of about his own height. The driver must take care to see that the yoke, skeys and strop used are smooth and will not hurt him. Every inducement should be made to get him along without hurting him.

If, once his initial fright is over, the young ox can be made to understand what is wanted of him without hard beating he will make a better worker and will not lose condition nearly so much as one which has to be beaten a lot.

Not more than two untrained oxen should be in the team. This is as many as a driver can cope with and unless he is a good man he is better with one only.

The driver should have a sharp knife handy to cut the strop in case the young ox struggles, falls down and is in danger of being strangled by the strop. If the strop cannot be loosened by hand it must be cut immediately; the best place is at one of the loops where it is hooked on to the skey so that it is easier to mend. Many a young ox has died because the driver had no knife handy or failed to cut the strop quickly.

Care is needed to see that the young ox is not overworked, especially during the first days when hard treatment may spoil him for life. The capacity of the beginner must be rated as half that of the trained ox. He can be worked during the mornings and be rested in the afternoons or be worked for three days a week and rested for four days. After he has been working for some weeks he should be able to do a full day's work every day of the week provided he is well grown and there is plenty of feed.

At the risk of appearing to dwell too much on the subject of ill-treatment it is necessary to emphasize strongly that the farmer must take great care to prevent the young ox from being broken in spirit. There is a vast difference between a healthy, hard, thin ox and an over-tired animal. Once he is overworked beyond a certain point *he will never recover,* he has lost his spirit and shows it by looking miserable and not feeding properly. He may linger on for a few weeks or months but he will never pick up again. This applies to old oxen as well but, of course, they are tougher and can stand more.

An ox should always be given a two-syllable name. He does not appear to understand a name of one syllable and does not respond to it.

Beating an ox without calling his name is a crime and should be stopped at once. When an ox is required to make an effort his name is called and if at the second call he does not respond he should then have a touch of the whip, and if he is trained and still does not respond he should then be beaten until he does pull, which will usually happen after a couple of hard strokes with the whip.

The driver who does not talk to his team should be avoided: too often the silent driver relies on the doubled whip which can do so much damage. Pain wears away flesh and spirit more rapidly than hard work.

Loud and continuous shouting and howling on the part of the driver is wrong; meaningless noise soon means nothing to the team and only tends to confuse them.

It is not good practice to train oxen with slow old beasts or with a team hauling a very heavy load. Half the trouble with ox draught is that often the pace is too slow. The young oxen should learn to walk at a good pace, for vehicles run more easily and tillage implements do better work if the speed is good.

Refusal to Work.—If the young ox refuses to work he should not be beaten with the double whip. If the driver cannot manage a long single lash with safety, he should be given a special short-lashed whip so that the danger of injuring the eyes of the oxen is reduced.

When the ox does not take kindly to the yoke he may be coupled up with a trained ox for a few days; from four to seven days is usually enough. The method of coupling is to tie loosely a long soft reim round the neck of each animal: each reim should go round the neck three or four times and be tied *so that it cannot slip tight and choke the ox.* Then another reim is used to link the two together, tied so that neither ox can get his forefeet into it.

When oxen are linked like this they must be watched carefully. They are in danger if they get amongst trees. The safest place for them is a paddock free from any snags on which they may get caught and choked by being alarmed and pulling their reims tight.

If the ox still refuses the yoke after this treatment the reim is replaced round his neck and one or two trek-chains are tied onto one side and then he will not be able to move without pulling something about. At first he

will probably make a great fuss but he will soon get used to the chain and start feeding. As a rule he gets so sick of the chain that a spell in the yoke comes as a pleasant change and he soon becomes a worker.

If a beast lies down and refuses to get up, his nostrils should be gripped and closed and then he will get up quickly. All cruel practices, such as putting burning grass to the animal, bending and breaking his tail, or cruel flogging, should be sternly repressed.

If decent humane methods fail to make a worker of the new ox he should be fattened up and sent to the butcher.

General Work and Management

The term span or team is generally understood to mean 16 oxen yoked in pairs. If more or less than 16 is referred to, one may use the expression a span or team of 14 or 18 oxen or, with smaller numbers, 2 yoke of oxen, meaning four animals, 5 yoke of oxen meaning ten animals and so on.

It is useful to make the normal place of inspan in the morning and of outspan in the evenings convenient for supervision. In the morning the master will be able to prevent sick animals from being inspanned and in the evening he will look out to see if any ox has been ill-treated during the day. These few minutes' daily supervision are extremely important for the welfare of the oxen, and indeed of the whole farm, for everything depends on the crops being manured, planted, cultivated and reaped at the right times and these operations cannot be done at the right times if the oxen are not capable of doing their work properly.

If a driver trains a team or a team gets accustomed to a certain driver he should be left with his team and not changed. Oxen work better for someone they know well.

A team which has been on road-work for some time may not work well for two or three days when put back to field work. This should be remembered and patience be exercised.

Road Work.—No one should be allowed to ride on a heavily loaded vehicle.

No team should take the road without a leader and the driver should see that he walks on the right line so that the team and vehicle can negotiate corners comfortably, without running up banks or into gutters.

The position of the brake boy is by the brake-handle and he should be taught to help the rear oxen when going down hill by sufficient braking to keep the vehicle *just going* without being pulled. Going down hill should be a rest for the team. The damage to wheels by locking them and the alternative horror of a runaway loaded wagon should also be explained to a new brake-boy, who should be intelligent and amenable, for he is partly responsible for a costly outfit.

When going up very steep hills with a big load the team should be rested once or twice by halting and putting stones under the rear wheels. These stones should not be left in the road. If blocks of wood are carried for this purpose they are not likely to be left behind to cause damage and will help to remind the driver of his duty.

In hot, dry moonlight weather it will help to keep the oxen in condition if road transport is done by night. Trips early and late to avoid the greatest heat of the day also help. A lantern should be provided for night work and the driver told to send the brake-boy ahead with it at road or rail crossings to give warning of the approach of the team.

As far as possible oxen should feed at regular hours and, if a team has to go into a township where there may be no grazing, it will be necessary to send fodder on the wagon and to warn both the driver and brake-boy to water the animals.

A good rule to observe in loading is that if the wagon and team can take 50 bags, then load 45. This will mean longer life for oxen and wagon.

Greased axles help the oxen as well as the life of the wheels.

Work on the Farm.—When carts and wagons are sent round the farm to collect manure, fuel, stone or whatever it may be, it pays to clear tracks even if they will be used rather infrequently. After a time the farm will have a number of reasonably smooth tracks (which should not be divested of grass) and much wear and tear of oxen, implements and carts will be saved. The passage of a cart over rough ground is harder, particularly for the wheelers.

In all farming operations where oxen are used, it can be taken as a rule that the quicker the walking pace the more easily a given amount of work is done by the oxen and the better the quality of the work. This is particularly true with mowers, self-binders and grain drills, which are designed to work at a certain speed for efficient service; below that speed it is very hard both on oxen and implements. The same objection applies, of course, to over-driving, which results in the oxen

breaking into a trot now and again. With a mowing machine, for example, if the speed is too slow the knife in the cutter bar will blunt itself on woody stems (such as those of the sodom apple) whereas at the right speed the knife will shear through them without strain. Too slow a speed strains implements as well as increases the draught to the oxen.

When cutting corn or hay it is a good system to work with two teams and sets of men for each implement. Each team does two hours on and two off. No time need be wasted as the relieving oxen are inspanned five minutes before time and as the tired oxen are unhooped and led off to be outspanned the new lot are hooked in. With well trained boys the change only takes two minutes. Working in this way it is possible to treble the acreage dealt with by a single team working ordinary hours. It is too much for the oxen to have to step out quickly for longer than two hours at a stretch. A tired team crawling along will do much less work in a given time and cause more halts and breakages with a reaper and binder where a certain speed is essential to avoid clogging of straw on the platform and strain on the packing and binding parts of the discharge arm.

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A CENTURY OF FARM RESEARCH

With our British tendency to understatement we may be inclined to give insufficient recognition to the fact that, in celebrating its Centenary, Rothamsted has made it plain to the world that it is the oldest agricultural research station in existence. A hundred years ago the German chemist Liebig had begun to apply his knowledge to the problems of plant growth. Sir Henry Gilbert, then a young student at the University of Giessen, became interested in the subject, and when he returned to this country he made contact with Lawes, who was engrossed in the chemistry of his home farm.

Lawes and Gilbert together started in 1843 a series of experiments which were to be the forerunners of many others in this and other countries. And great as has been the development of agricultural science in Germany, Russia and America, it is right that we should remember the distinguished place Rothamsted holds as the world's oldest agricultural research station.

In these days, when many County Executive Committees have a dozen or more demonstration farms, and when farm institutes provide a useful medium for passing on modern information, it is as well to be clear about the function of fundamental research. Most of the things seen by a farmer visiting a research station would have little direct practical bearing on his business. It is not intended that they should. Research is the pursuit of knowledge, and, from the accumulation of accurate information which it produces, the technologist can obtain the data from which improved methods and materials can be developed.

The technical advisers, with the agricultural teachers and demonstrators, are the proper channels for applying science to practice. They have to be in close touch with what the Minister referred to as "the actual rough-and-tumble" of day-to-day practical farming. But they must be able to count on a sound basis of reliable and up-to-the-minute scientific knowledge. This conception, in fact, was the theme of all the speakers at the Centenary meeting of Rothamsted. Important as are the applications of agricultural science to farming practice, it is essential that the source of knowledge should be the research centre, equipped with modern material and staffed by men and women who are trained to examine each problem from a fundamentally scientific point of view.

"Science is not yet as expensive as war—but it is getting on." This is how Sir John Russell put it, to describe the requirements for keeping this country abreast of competitiors, and the Rothamsted Centenary serves to underline this fact. Fundamental scientific research must not be sacrificed to practical application, for the two are complementary.

Farmer and Stockbreeder.

FEEDING VALUES OF DIFFERENT VARIETIES OF PUMPKINS FOR LIVE STOCK

By M. H. French, M.A., Ph.D., Veterinary Laboratory, Mpwapwa, Tanganyika Territory

Pumpkins form a valuable succulent foodstuff for almost all classes of farm live stock and are of particular value in areas with a low summer rainfall and a long dry winter. In these areas, green fodders are not available in the winter unless grown under irrigation or preserved in the form of silage. Most of Tanganyika is supplied with insufficient water for irrigation and so pumpkins could fit into normal farming practice with great advantage to the live stock. It was therefore decided to determine the feeding values of four distinct varieties cultivated by natives, chiefly for their own consumption, together with three other varieties obtained from South African Dutch farmers and originating from the Union.

The pumpkin is a warm-weather plant and grows best on fertile, friable and well-drained soils. It responds considerably to organic manures and should always be planted on well-cultivated land which has received a liberal application of farmyard or kraal manure. Although pumpkins are stated to be fairly drought-resistant, a long break in the rains seriously retards the plants and may even kill a number. They are not advised where the rainfall is less than 22 inches nor where a bad rainfall-distribution is likely to subject them to several dry spells because, under these conditions, the yields will be disappointingly low. In certain years the pumpkin-fly causes a serious reduction in the yield because the larvæ cause affected pumpkins to rot quickly.

The native practice in this Territory is to plant pumpkins amongst the maize or millet crops but this is not advised because (*a*) the cereal plants shade the pumpkins and (*b*) the competition for soil moisture and nutrients causes both crops to give smaller yields.

Pumpkins can be stored and fed in their natural state and no preparation is necessary beyond slicing them into smaller pieces with a spade. To get the best keeping properties, pumpkins should be allowed to ripen off in the field and not be harvested too soon. A certain amount of drying in the field is an advantage in that the coats become harder so that the keeping properties are enhanced. If pumpkins are harvested before the plants die off and care is not taken to avoid breaking the stalks or bruising the skins, considerable losses through rotting will occur during storage.

In South Africa, there are many varieties of pumpkins—the sweeter, smaller, finer-grained types are grown for human consumption and only the larger coarser kinds are fed to stock. Pumpkins have a coarse outer rind, which protects the flesh, and a large central cavity containing the seeds. The shape varies from spherical to oblong, the size from a few inches in diameter to huge pumpkins weighing upwards of 100 lb. each; and the colour may vary, with type, from single colours such as greenish-white, green, yellow and even orange, to complicated variegated patterns of these colours.

Of the seven varieties examined it is unfortunately only possible to give two (the Boer and Selonse Pumpkins) their proper names. The other one originating from South Africa has had to be called after the farmer from whom the seed was collected. Of the four native types three are given the local Ugogo name and the fourth is called after the European who first brought it to my notice. The seven varieties all appear to breed true to type, though cross-pollination and intermediate types will occur when the different varieties are planted close together. A brief description of each variety examined is given below:—

Boer Pumpkin.—This pumpkin, from a local farmer, can be regarded as typical of the pumpkins bearing this name in the Union. It is a hard variety with a yellow-grey skin and very good keeping qualities. This is a large, rather coarse type which is roughly spherical but is slightly flattened top and bottom. The flesh is a yellow to pale orange.

Selonse Pumpkin.—Yellow-skinned with yellow to orange flesh. The rind is not very hard and it bruises easily, so that its keeping properties are considerably reduced by rough handling. It is round to oval in shape and the flesh is not so coarse as in the Boer type.

"Laubsher" Pumpkin.—The correct South African name of this variety is not known. It breeds true and is marrow-shaped though somewhat shorter and fatter than the common vegetable marrow. The skin is tough but not hard, so that the flesh bruises easily. It has longitudinal ribs and the colour is yellow-green with orange-yellow stripes between the ribs. The flesh is yellow and fine-grained and quite pleasant for human consumption.

"Culwick" Pumpkin.—This native variety was obtained from the Kiberege District, the seeds being supplied to me by Mr. A. T. Culwick. It is a thin marrow shape with pointed instead of blunt ends, and is green in colour with a yellow-brown mottling on its tough skin. It has good keeping properties, is not coarsely grained and has orange-yellow flesh.

"Mamusa" Pumpkin.—This is a small local Ugogo variety which is spherical or shaped like a rugby football and has a hard yellow-brown skin. The flesh is dirty yellow and the seeds are small.

"Majenge" Pumpkin.—This is another Ugogo pumpkin which is roughly spherical in shape but with flattened tops and bottoms. It is a grey-green colour with white stripes. The skin is not so hard as in the "Mamusa" type and it does not keep so well. The flesh is very pale yellow.

"Mahikwi" Pumpkin.—This variety is also of local Ugogo origin but is much larger than the two previous types. It is dark green in colour with white stripes and is roughly spherical. The skin is very tough and the flesh white. Although known locally as a pumpkin this variety should really be classed as a melon because it has no central cavity and the red seeds are embedded in the white flesh.

To determine their feeding value the whole pumpkins (rind, flesh and seeds) were fed sliced to native sheep together with a basal ration of chaffed hay. Moisture determinations were carried out daily on the sliced pumpkins and the dry-matter residues were bulked together for analysis. Table I gives the dry-matter compositions of the seven types together with the average dry-matter contents of the fresh pumpkins.

This table shows the very watery nature of pumpkins, above all the Mahikwi, when fed in the natural state. The Mahikwi variety was also less rich in proteins and soluble ash constituents than the others but contained a higher proportion of fibre. With this one exception, the dry matters were rich in crude protein and they should thus be of great value to the live stock industry, as they contained nearly twice the protein content found in the dry matters of such root crops as mangolds, turnips and swedes. They also contained less soluble carbohydrates than these roots but were richer in fibre and ether-soluble matter. The pumpkin fibre content varied, but this was to be expected since the average size of the different types fed was not the same and the fibre content will be proportional to the amount of rind. The contents of ether-soluble matter and of soluble ash were high whilst the ash was rich in those minerals of value to live stock.

Henry and Morrison (*Feeds and Feeding*, 19th edition, 1928) give the average composition of four American samples of field pumpkin, on a dry matter basis, as 16.87 per cent crude protein, 6.03 per cent ether-soluble matter, 50.60 per cent N-free extractives, 15.66 per cent crude fibre and 10.84 per cent total ash. The Mpwapwa samples thus contained more protein and ether-soluble matters and a little more fibre than the American samples.

The dry matter of pumpkins is also very different from that of natural grazings, green crops grown under irrigation and silage, which are the foods they could replace in the dry season. It is much less fibrous but richer in protein, ether-soluble matter and soluble ash. In fact it is difficult to compare the pumpkin's dry matter with that of any other local food-

TABLE I

DRY MATTER CONTENTS AND COMPOSITIONS OF PUMPKINS (Figures Percentage)

	Selonse pumpkin	Boer pumpkin	Laubsher pumpkin	Culwick pumpkin	Mamusa pumpkin	Majenge pumpkin	Mahikwi pumpkin
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Dry Matter	11·10	8·15	14·00	18·85	17·50	12·85	7·05
Crude protein	20·64	20·85	18·28	17·82	20·51	24·02	10·15
Ether extract	5·39	9·18	10·15	10·14	8·04	7·89	6·67
N-free extract	54·93	41·48	37·68	43·20	45·56	38·63	54·46
Crude fibre	10·36	17·85	26·36	18·05	18·58	19·48	21·93
Total ash	8·68	10·64	7·53	10·79	7·31	9·98	6·79
SiO2	0·68	0·63	0·38	0·61	0·17	0·09	0·32
SiO2-free ash	8·00	10·01	7·15	10·18	7·14	9·89	6·47
CaO	1·100	1·238	0·792	0·939	1·005	0·739	0·705
P2O5	0·441	0·510	0·575	0·445	0·613	0·592	0·512
K2O	3·256	3·356	2·597	3·216	2·446	3·293	2·286
Na2O	0·642	0·742	0·771	0·864	0·665	0·562	0·522
Cl	0·674	0·768	0·783	0·627	0·437	0·564	0·581

stuff, though coco-nut cake is perhaps the most similar in general composition.

Henry and Morrison, when discussing the feeding of pumpkins, state that the seeds should not be removed because they contain much nutrient matter. In order to show this more clearly the seeds of two varieties given in Table I have been analysed and set out in Table II.

TABLE II

COMPOSITION OF PUMPKIN SEEDS (Dry matter basis)

	Culwick pumpkin seeds	Mahikwi pumpkin seeds
Crude protein	34·96	18·58
Ether extract	25·20	21·15
N-free extract	17·45	27·79
Crude fibre	18·69	29·03
Total ash	3·88	3·45
SiO2	0·20	0·10
SiO2-free ash	3·68	3·35

These figures compared with those in Table I show the great difference in composition between the seeds and the whole pumpkins. Removal of the seeds before feeding would thus result in the loss of valuable protein and ether extract.

The digestibility trials ran smoothly and no troubles were encountered and no digestive disturbances produced. Table III gives the average digestibility coefficients for the seven pumpkin varieties examined.

These figures reveal the interesting fact that, whereas all varieties of pumpkin were well digested, the three South African and Culwick's Kiberege pumpkins were highly digestible and more so than the three Ugogo varieties. All components of the dry matter were very digestible, though the fibrous constituent of the three Ugogo pumpkins were less efficiently digested than any of the other constituents.

I have occasionally been asked whether pumpkins should be boiled before feeding to pigs. No advantage is to be expected from boiling and the seeds appear to be well digested, as none are obviously present in the dung from pigs fed generous quantities.

The digestible nutrients and starch equivalent values have been calculated and are shown in Table IV. As no "availability" numbers could be found in the limited literature at my disposal, the starch-equivalent values have been calculated by means of Kellner's correction according to fibre content.

As would be expected from the dry-matter compositions in Table I, the melon-like Mahikwi variety contains much less digestible protein than the other types, which are rich in digestible protein and therefore have very narrow nutritive ratios. The three Ugogo varieties had much lower starch-equivalent values than the other four.

Since pumpkins are such very watery foods, dry-matter compositions are liable to be very

TABLE III

AVERAGE DIGESTIBILITY COEFFICIENTS FOR PUMPKINS

Variety	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	N-free extract
Selonse	94·08	94·77	87·37	87·01	92·42	98·74
Boer	85·63	85·89	81·73	92·51	85·36	86·74
Laubsher	79·95	81·12	83·54	98·46	69·18	83·61
Culwick	87·46	87·73	88·51	87·78	67·58	95·81
Mamusa	69·04	69·14	78·82	85·72	47·63	70·63
Majenge	69·47	69·15	76·08	79·20	55·16	69·88
Mahikwi	63·80	66·69	62·34	93·49	55·33	68·79

TABLE IV

DIGESTIBLE NUTRIENTS AND STARCH EQUIVALENT VALUES OF PUMPKINS
(Per 100 parts dry matter)

	Selonse pumpkin	Boer pumpkin	Laubsher pumpkin	Culwick pumpkin	Mamusa pumpkin	Majenge pumpkin	Mahikwi pumpkin
Digestible crude protein ..	18·03	17·04	15·27	15·77	16·16	18·27	6·33
Digestible ether extract ..	4·69	8·49	9·99	8·90	6·89	6·25	6·23
Digestible N-free extract ..	54·24	35·98	31·50	41·39	32·18	26·99	37·46
Digestible crude fibre	9·57	15·24	18·23	12·20	8·85	10·74	13·13
Digestible organic matter ..	86·53	76·75	74·99	78·26	64·08	62·25	62·15
Starch equivalent	85·28	73·11	67·87	74·94	58·60	55·54	54·72
Nutritive ratio	1 : 4·2	1 : 4	1 : 4·5	1 : 4·5	1 : 3·3	1 : 2·7	1 : 9·7

misleading and it is also advisable to calculate their feeding values in their natural state. In Table V they are compared with other succulent foods.

TABLE V

DIGESTIBLE PROTEIN AND STARCH EQUIVALENT VALUES OF SUCCULENT FOODSTUFFS IN THEIR NATURAL STATES

Succulent Foods	Dry matter content	Digestible protein	Starch equivalent
	Per cent	*Per cent*	*Per cent*
Selonse pumpkin ..	11·10	2·0	9·5
Boer pumpkin ..	8·15	1·4	6·0
Laubsher pumpkin ..	14·00	2·1	9·5
Culwick pumpkin ..	18·85	3·0	14·1
Mamusa pumpkin ..	17·50	2·8	10·3
Majenge pumpkin ..	12·85	2·3	7·1
Mahikwi pumpkin ..	7·05	0·4	3·9
Dry-season green lucerne	30·00	4·3	12·7
Maize silage	25·00	0·3	9·4
Green maize (6-7 feet)	20·0	1·0	9·5
Green millet (6-7 feet)	25·0	1·1	10·4
Green bulrush millet (4-6 feet)	20·0	1·8	8·0
Green napiers fodder (3 feet)	20·0	1·0	7·0
Green guinea grass (3 feet)	15·0	0·6	5·3
Globe mangolds* ..	13·2	0·7	6·8
Swedes*	11·5	1·1	7·3
Turnips*	8·5	0·6	4·4

*Taken from *Rations for Live Stock*, Wood and Woodman, 1932 Edition.

These figures show that pumpkins compare well with the other succulent foods which might be fed in the dry season, and that green lucerne is about the only food which surpasses them in general feeding value.

Pumpkins are palatable to all classes of live stock, whilst donkeys and pigs show a very marked liking for them. They are a safe food for horses, donkeys, cattle, milk cows, sheep, goats, poultry and pigs and, unlike silage and other green crops, they do not have the disadvantage of containing too much fibre for the last two classes of animals.

One occasionally hears, in farming circles, that pumpkin seeds cause paralysis in certain types of stock. No such symptoms have been observed at Mpwapwa and Steyn (*Onderstepoort J. Vety. Sci.* 5 (1935), 441) fed large quantities of seed without producing toxic symptoms in sheep and rabbits.

A further interesting point about pumpkin seeds is their reputation and use as a cure for tapeworm. Though they have long been so used the evidence of their efficiency is very contradictory and is now considered rather doubtful.

In this article no mention has been made of the yields to be expected from these different varieties because mean yields vary so from district to district and year to year that comparative yields for three seasons under Mpwapwa conditions are not thought to be of general use. The results of the feeding trials suggest that a fodder pumpkin of repute, purchased from a seedsman, is likely to prove of the greatest feeding value and should be grown in preference to local native types provided their yields are at all comparable.

Because pumpkins can give high yields of stock food under good conditions, they are worth serious consideration as a winter succulent in this Territory for all classes of stock, and especially for milk cows, poultry and pigs. Their value cannot be assessed simply in terms of starch equivalent and digestible protein values. They also have a tonic action on the sluggish alimentary movements of the later dry season, stimulate appetite and certain varieties are rich in carotene, the precursor of vitamin A, which is so badly needed by stock in the dry season when their normal supplies of this vitamin and its precursor have disappeared.

Summary

1. Pumpkins have as good a nutritive value in their natural state as the other dry-season succulents, such as green fodders, silage or roots, but are not quite equal to lucerne grown under irrigation. They are palatable to all classes of stock.

2. Three local Ugogo pumpkins have been found not quite so digestible or of such high feeding value as three other varieties which originally came from South Africa and another type obtained from the natives of the Kiberege District.

(*Received for publication on* 9*th June*, 1943)

There are two pre-requisites to successful research—a clear formulation of the questions to which answers are to be sought, and the provision of experimental methods capable of answering them.

H. Ballantyne quoted in *Chemistry & Industry*.

A SCIENTIFIC IMPARTIALITY

Where the female differs from the male is in being more infantile: where the male differs from the female is in being more ape-like and senile.

A. C. Haddon (the anthropologist)

LARGE-SCALE WHEAT PRODUCTION AT OLDEANI, TANGANYIKA TERRITORY

By N. R. Fuggles-Couchman, B.Sc., C.D.A., A.I.C.T.A., Agricultural Officer, Tanganyika Territory

The following review of large-scale production of wheat is based on very detailed observations made, and data collected, by Mr. C. Redfearn, General Manager for the Custodian of Enemy Property, of a large group of enemy estates at Oldeani, Tanganyika Territory. The estates under Mr. Redfearn's management include some 3,300 acres of coffee and 1,000 acres of maize and beans, the farms being grouped under three group managers, so that his undertaking the production of 2,400 acres of wheat was no inconsiderable task, and, as shown by the results obtained, Mr. Redfearn is to be congratulated on the success of his operations.

The Oldeani farms were owned almost entirely by Germans before the war. As the farms are over 100 miles from railhead at Arusha, transport costs were heavy and coffee was the chief crop grown, as it could carry those costs. Only small acreages of wheat were grown. The rise in price of wheat after the outbreak of war, and later the guaranteed price of Sh. 25 per bag, made it more economic to grow wheat in the Oldeani area and considerable extensions in acreage were made.

The farms taken over by the Custodian of Enemy Property lie on the south and south-eastern slopes of Oldeani Mountain and the Ngorongoro Crater, running down from the forest edge into the open *Balanites-Themeda* savannah of the Karatu area of Mbulu. The upper area consists of a number of more or less narrow ridges separated by deep, steep-sided valleys. In the lower areas the ridges are considerably wider and of much more gentle slope. One or two blocks, on ridge tops, were rather exposed to the prevailing wind, but in general the fields were fairly well sheltered. Rust or heavy crops appear to have caused more laying of the crop than wind. The deep valleys running through the area make east-and-west transport awkward and this factor made the management of the wheat farms more difficult as blocks of wheat had to be somewhat scattered, with consequent loss of valuable time in the transport of implements from one block to another. The distance between the furthest blocks east and west was about 19½ miles by road, and from the lowest to the highest 6 miles.

Eight main blocks of land at altitudes of 4,900 to 5,600 feet and varying in size from 110 to 854 acres were put under wheat. Four of the blocks were subdivided by planting two or more varieties of wheat in them. This variation in altitude, together with the resulting variations in rainfall, introduced a further problem, the choice of variety and planting date, to ensure that the harvest period might be sufficiently spread out to enable the harvesting to be done with the limited machinery available.

All blocks were on more or less sloping land, in most cases of irregular slope. The slope over any large area rarely exceeded 5 per cent, but small parts of some blocks were over 8 per cent. These have now been abandoned, owing to the difficulty of working the combine harvesters on such slopes, and to the danger of accelerated erosion.

Soils

All the Oldeani soils are of volcanic origin, rich in phosphates and generally well supplied with organic matter. They vary from a free-working red loam in the lower areas, to a deep black rich loam in the middle and higher areas. The red soils are more easily worked than the heavier dark soils, but dry out more quickly in hot weather. They are also more inclined to cake into hard lumps after rain if not kept in good condition. What is considered some of the best wheat land in Oldeani lies in the dark loams of the middle area at Karatu. From Mr. Redfearn's records yields appear to have been lower from the dark soils than from the red soils, but this may be the result of the abnormally heavy rainfall, which made planting difficult, brought on heavy weed growth and caused some laying of the crop on the darker soils.

Over half the total area was newly broken land, and, generally speaking, yields from the new land were rather lower than from the old arable. Yellowing of the wheat, due to continuous heavy rain, appeared to be worse on new land.

The old land had been previously cropped from one to four years, with periods of fallow in some fields. Previous cropping and yields from some blocks are given in Table 1.

TABLE 1

Block	Area	Previous to 1939	1939	1940	1941	Yield	1942	Yield (bags of 200 lb.)
								Per acre
II ..	184	No crop ..	No crop	No crop	30 acres maize 154 acres wheat	5·36	Wheat	6·00
III ..	334	No crop ..	No crop	No crop	Wheat ..	3·47	Wheat	*2·00 5·75
IV ..	266	Maize	Maize	Maize	Wheat ..	3·51	Wheat	4·50–5·32
V ..	108	Maize ..	Fallow	Fallow	Fallow ..	—	Wheat	4·42–5·20
VI ..	25	Two crops maize	Maize	Maize†	Fallow ..	—	Wheat	4·75–8·47

N.B. 1941 was a drought year. *Rusted Australian wheat. †No crop droughted.

Climate

1942 was a year of early and heavy long rains throughout the Northern Province. At Oldeani the long rains were characterized by continuous cold, misty, sunless weather during the growing season. Mr. Redfearn in his report says "Rain definitely created one of our major problems. From the middle of December, 1941, until the end of June, 1942, generally speaking, the only two dry spells experienced were the month of February and the second half of March. Ploughing and harrowing the 2,412 acres and then endeavouring to keep this area clean until planted was a difficult task". Nevertheless, by the use of some hand labour Mr. Redfearn successfully overcame that difficulty, and when I visited Oldeani during the harvest I was most impressed by the clean weedless condition of most of the wheat lands.

The rainfall recorded at gauges nearest to the several blocks showed considerable variation not only between blocks, but within blocks. The lowest total rainfall for the months March-July was 12.2″ and the highest 29.8″. In the lower, red-soil, areas to the west the rainfall was lower, between 12.2″ and 22.5″, the highest being recorded on Block I, which is in the middle area. On the heavier soils of the middle and higher elevations, and further to the east rainfall was generally heavier, between 24.7″ and 29.8″. 7″ of rain fell in one night on the lower area of Block V. Rain fell for 50 days from the date of planting Block I (22-26 March) to the end of May, and for 38 days after planting Block III, which caused considerable yellowing of the plants. Yellowing also occurred in all other blocks, except Block II, which was the first block planted and where no rain fell for 17-18 days after planting.

In June and July there was excessive misty damp weather, particularly in the higher areas, and even in September mists lay over the higher fields until 10.00 hours. The sunless weather caused the collapse of the straw in the Kenya Governor in Block IV.

Temperature records are unfortunately almost non-existent. A casual and incomplete record in 1943 gave a minimum reading of 9°C (48°F) at 5,600 ft. This was near Block IV from which, in 1942, 4½ bags per acre of Kenya Governor were harvested. No reliable figure is available for the maximum temperature nor is the month known in which the minimum was recorded, but it was probably in late June or early July.

Field Husbandry

Mr. Redfearn believes in ploughing his land as soon after harvest as possible, and breaking new land before the short rains in order to allow maximum time for the vegetable matter turned in to rot down. All straw thrown out by the combine is turned in; none is burnt. He also likes to harrow twice, or cross-plough and harrow once, before the short rains. When breaking new land the ploughs were set rather more shallow, to turn the grass roots out; the cross-ploughing was generally deeper. On old land the usual depth of ploughing was about 6-7″. After the short rains newly broken land was cross-ploughed, and both new and old land harrowed down. This should have been sufficient to obtain a clean seed-bed. The prolonged and early rains, however, made it impossible to keep the weeds in check. As many as three ploughings and five harrowings were necessary in one block, and even then hand-weeding was necessary after the wheat had germinated.

The machinery available consisted of three tractors, one TD9 and two TD6, as well as one other old tractor which helped on occasions, but was most unreliable. Only one tractor had lights, and the TD9 was out of commission for 3½ months during the harvest. One 5-furrow and two 4-furrow disc ploughs were available, and two 10 ft. and one 7 ft. disc-harrows. For harvesting Mr. Redfearn had two No. 22 combine harvesters and one reaper binder. From these data it will be appreciated that the whole machinery was well utilized in the management of 2,400 acres.

Oxen were also used on one small block for the cross-ploughing and harrowing and a contractor ploughed and harrowed 160 acres. Mr. Redfearn had three European assistants in the field, who drove tractors, supervised drilling and operated the harvesting machinery.

Of the 2,412 acres, 2,100 were planted by two 19-row disc drills; the remainder was broadcast by hand. Drilling commenced on 9th March and was completed in 43 days, giving a daily average of 49 acres. On two days in March, on red soils, during a dry spell, 90 acres per day were drilled by the two drills. The general average per day must be considered good in view of the very wet April.

The few South African farmers in the Oldeani area, who have planted small areas of wheat for some years, consider 50 lb. per acre to be the best seed rate. Mr. Redfearn followed local practice, with two variations intended as a trial. In adjacent areas seed rates of 40 lb. and 60 lb. per acre were used, for different varieties, and on another block 42 lb. and 56 lb. per acre for the same variety. No differences in yield were noted, and could hardly be expected, as this is a subject for proper experimentation. At first sight 50 lb. per acre seems a very low seed rate, and if yields of 7¾ bags per acre can be obtained from that low rate, it does seem possible that a somewhat higher seed rate would give higher returns. Some of the wheat I saw at harvest struck me as being a little thin on the ground.

No manure or fertilizers were applied to the crops, crop residues alone having been ploughed in on the old land. The soils are naturally so rich in phosphates that it is unlikely that phosphatic fertilizers will be required for some years. Local farmers have used the same land for wheat for nine successive years and in the period have averaged from 5½ to 10 bags of 100 kilos per acre.

The four main varieties planted were Kenya Governor, Australian 26A, a variety which had become very popular in the area owing to its strong straw and good yield, Simpson's Rongai and Simpson's L3. A small area of 192 and B 256 G were also planted for seed purposes. Planting was started on 9th March and was completed on 30th April, but 2,000 acres had been planted by 8th April. Mr. Redfearn considers that planting was about a fortnight too early, but after a heavy short-rains season a short long-rains season had been expected. As mentioned above, since the varieties planted had different periods to maturity, and blocks were at different altitudes, planting dates had to be carefully chosen in order to stagger the harvest sufficiently for the harvesting machinery to deal with the harvest. Most of the lower areas, rather over half of the total acreage, were planted in March, in which month 400 acres of Australian, 328 acres of Simpson's Rongai, 560 acres of SL3 and 148 acres of Kenya Governor were sown. In the first week of April a further 225 acres of Australian and 338 acres of Kenya Governor were planted. The remaining 32 acres of Australian, 140 acres of Kenya Governor and 233 acres of SL3 were planted between 10th and 30th April.

The germination and stand of all varieties were generally good to excellent on all old land, but in several areas of new land they were rather poor and patchy. A rather heavier seed-rate may be advisable on new land. The

TABLE 2

PLANTING AND HARVESTING DATES OF WHEAT AREAS AT OLDEANI, SHOWING ALTITUDES

Variety	Area	Date of Planting	Date of Harvesting	Altitude
	Acres			Feet
KG	148	9–13 March	20–23 July	4,900–5,000
SR	328	14–17 March	25 July–10 August	5,000–5,100
Aust. 26A ..	75	14–22 March	—	5,100–5,200
SL3	378	17–21 March	11–21 August	5,100–5,200
Aust. 26A ..	178	22–25 March	27–30 August	5,150–5,250
Aust. 26A ..	148	22–26 March	22–26 August	5,200–5,300
SL3	172	25–29 March	31 August–9 September ..	5,100 5,150
B.192.. ..	9	27 March	5 September	5,300
KG	116	30 March–1 April	30 August–3 September ..	5,400
KG	112	30 March–8 April	3–9 September	5,500–5,600
Aust. 26A ..	225	2–8 April	—	5,100–5,200
SL3	233	10–16 April	15–26 Sept. (Mature 8 Sept.)	5,100–5,300
KG	110	13–18 April	3–7 September	5,300
Aust. 26A ..	32	17 April	23–25 Sept. (Mature 4 Sept.)	5,100–5,300
KG	85	19–20 April	8 September	5,300
KG	17	19–20 April	3 October	5,300
B256G ..	8	18 April	3 October	5,400
KG	38	22–30 April	24–26 September	5,500–5,600

only operation after drilling was some hand-weeding in the most weedy blocks.

Harvesting commenced on 20th July and was completed in 76 days. It was possible to use the combined harvester on 1,975 acres: 237 acres, which were badly laid or on rather steep slopes, were cut by hand and binder. The remaining 200 acres were so badly spoilt by Stem Rust (*see* below) that they were not worth harvesting. With the exception of 32 acres of Australian 26 A and 233 acres of SL3, it was possible to harvest all the wheats as they matured. The former stood up to three weeks after maturity, but there was no apparent loss from shattering. As mentioned above, all blocks were on more or less sloping land. The combines worked satisfactorily on slopes up to 12 per cent as long as the machine had to cover only short pieces across the slope. There was some delay due to the choking of the straw-walkers where the combines had to traverse such slopes for any considerable distance. Mr. Redfearn has now eliminated the majority of such slopes from his wheat areas. The combines had an 8 ft. cut and averaged 14 acres per day, with a TD6, the best day giving 22 acres per machine.

Stem Rust

Stem Rust was bad in 1942 at Oldeani, above all on Australian 26 A. This variety was first tried in 1940 by a local farmer. The results were so good that in 1941 two farmers planted small areas with the available seed, obtaining yields of $13\frac{1}{2}$ and $11\frac{1}{4}$ bags per acre. The short strong straw, compared with the weak straw of the commonly grown Kenya Governor, the high yield, and the property of holding the grain in the ear long after maturity had been reached, made the variety so attractive to the local farmers that in 1942 they planted 65 per cent of their 870 acres with Australian 26A. As a result of the heavy attack of Stem Rust several farmers lost their entire crop and only 2.3 bags per acre were harvested. Mr. Redfearn, who planted 27 per cent of his acreage to Australian 26A, also suffered considerably, losing some 30 per cent of his entire acreage of that variety, and reaping only 2.1 bags per acre from the rest, compared with an average of 5.5 bags per acre from 1,739 acres of the other three varieties.

Tests made under difficult conditions by Dr. Nattrass of the Kenya Department of Agriculture, for the Plant Pathologist, Tanganyika, on the rust prevalent at Oldeani in 1942, showed it to be almost certainly the form K6. K3 was also probably present on what was believed to be DC x Ceres 721, and K5 had been isolated previously in 1938 on Kenya Governor and on other small lots of varieties under trial there. In 1942 Kenya Governor was only very slightly infected by rust, possibly the form K3 which was present in Oldeani; there was an even lighter infection on Simpson's Rongai and SL3. The rust caused no apparent damage to those varieties. 192 and B 256G showed no signs of rust at all.

Stem Rust was first observed on 3rd June on Australian 26A sown between 22nd and 26th March. By 6th July it had spread over one-third of the block and by the middle of August the whole block was infected. 3.9 bags per acre were harvested from that area. Another block was infected about the same time from a patch of Australian 26A wheat, belonging to a local farmer, planted nearly three weeks earlier. 87 acres were not worth harvesting and only two bags per acre of poor-quality grain were reaped from the other 91 acres. A third block of Australian 26A, sown between 14th and 22nd March, became infected on 23rd May, the rust quickly spread through the 75 acres and then infected an adjacent block planted between 2nd and 8th April. No crop was obtained from the 75 acres and only 1.5 bags per acre from the remaining 225 acres. Another adjacent block of 32 acres, planted on 17th April, was infected about 1st August, but although the whole area was heavily infected by 16th September, ears were well formed and 4.3 bags per acre were harvested. The rust generally spread, with the prevailing wind, from earlier-sown blocks to later-sown blocks downwind. After his visit to Oldeani the Plant Pathologist, Tanganyika, suggested that, so far as practicable, any one area should be planted within as short a period as possible, and planting should commence on the down-wind side to minimize infection by wind-borne spores from infected earlier sowings. Mr. Redfearn eliminated Australian 26A from his planting programme for 1943.

Leaf Rust infection varied from little or none to considerable infection in the different fields. The Plant Pathologist remarked on the amount of this fungus which the plant will tolerate without appearing to suffer. No Yellow Rust was recorded.

Black Chaff disease was generally present in small amounts in all varieties, with the exception of one block of Australian 26A, but did no apparent damage to the crop.

Game did some damage to small areas, especially near the forest. Birds were difficult to control at harvest and some loss of crop resulted. Ants also did some damage, reducing the stand in one or two areas of new land, but on the whole losses due to all three causes were slight.

Behaviour of the Varieties

Australian 26A.—In all blocks this variety had a short, strong straw which only collapsed where rust infection was heavy; this was more particularly the case on new land. The ears were short and stocky, and heavily filled where rust infection was less severe. The average height of the crop was 43″–45″. The grain was fairly bold but affected by rust. This variety averaged 151 days to maturity, ranging from 141 days in the lower areas to 159 days in the higher.

Kenya Governor.—Straw was generally rather thin, weak and inclined to crack and bend over, particularly where ears were heavy. The crop varied in height between 45″ on new land at lower altitudes, and 49″-52″ on new land, and 60″ on old land, at higher altitudes. Some of the early-planted blocks in areas of higher rainfall collapsed before cutting, some as early as six weeks after planting. Later-planted Kenya Governor generally stood well but some patches of heaviest growth collapsed after ten days of wet cold weather in early July. Ears were in all cases well filled, long and generally free from Black Chaff. The grain was bold and some of the latest-planted gave a bushel weight of 64 lb. Kenya Governor averaged the shortest period to maturity, 146 days, ranging from 134 days in the lowest areas to 156 in the highest areas.

Simpson's L3.—The variety grew rather taller than the others, varying from 53″ to 63″ on old land. The straw was very strong and there was no laying. Ears were generally well formed and rather long. One block of old land on red soil had a rather high percentage of defective ears, and there was some Black Chaff in one block on old land. The grain was generally good, and bushelled well. This variety was rather longer in maturing than the others, averaging 153 days.

Simpson's Rongai.—This was another long-strawed variety, with strong straw which did not collapse under the wet conditions. The average height was 54″. Ears were well formed, heavy and slightly infected with Black Chaff. The bushel weight averaged lower than in Kenya Governor and SL.3. The one block of this variety in the lower area matured at the same time as Kenya Governor.

B. 192.—The straw was exceptionally strong and thick, but the crop grew so high that in some patches the stems collapsed and continued growing from the bent position. Ears were very long and very well filled. Two counts gave 60 grains to the ear. This variety was planted at a rather high altitude. Mr. Redfearn, in commenting on the varieties, considers that 192 should be planted in drier areas, as the growth is too rapid in normal Oldeani weather. No Stem Rust was recorded on this variety. The period to maturity was 163 days.

B. 256 *G.*—A very fine stand was obtained from this wheat, which grew to a height of 60″. It stooled very heavily, to such an extent that no attempt could be made to weed by hand. Growth was extremely slow, and some adjacent Kenya Governor was 2 feet higher three weeks after germination, although planted on the same day. Ears were good, sound and well filled. No Stem Rust was recorded. This variety had the longest period to maturity of all, taking 179 days.

Yields

The yields of the different varieties are set out in Table 3, together with planting dates and other information.

TABLE 3

YIELDS IN BAGS OF 200 LB. OF VARIETIES OF WHEAT GROWN AT OLDEANI, 1942

Variety	Altitude	Area (Acres) New land	Area (Acres) Old land	Yield per acre	Overall average
KG ..	4,900–5,000	148	—	7·75	—
	5,400	110	—	3·44	—
	5,300	—	116	4·50	—
	5,500–5,600	—	112	4·00	—
	5,500–5,600	—	38	5·32	—
	5,400	85	—	5·38	—
	5,400	—	17	8·47	—
Total..	.. ..	343	283	—	5·29
Aust. 26A	5,200–5,300	148	—	3·90	—
	5,100–5,250	87	91	2·00	—
	,,	159	66	1·50	—
	,,	—	75	Nil	—
Total..	.. ..	394	232	—	2·10
SR. ..	5,000–5,100	285	43	6·15	6·15
SL.3..	5,100–5,250	194	184	6·00	—
	5,100–5,150	30	—	3·37	—
	,,	—	242	5·75	—
	5,100–5,300	134	99	4·42	—
Total..	.. ..	358	525	—	5·37
192 ..	5,300	—	9	5·20	5·20
B256G	5,400	—	8	4·75	4·75

With the exception of the badly rusted Australian 26A, the wheat produced at Oldeani was of a very high grade, as is shown in Table 4.

TABLE 4

GRADE OF WHEAT DELIVERED TO MESSRS. UNGA, LTD.—BAGS OF 225 LB.

Number of Bags	Variety	Grade				Average bushel weight No. 1	Percentage			
		1	2	3	Lower		1	2	3	Lower
1,209	Aust. 26A ..	20	—	245	944	—	1·65	—	20·30	78·10
2,110	KG ..	2,073	6	9	22	62	98·20	0·30	0·42	1·04
1,653	Rongai ..	1,576	15	50	12	61	95·30	0·91	3·02	0·73
3,402	SL.3	3,326	—	35	41	63	97·60	—	1·03	1·20
8,374		6,995	21	339	1,019	—	83·60	0·25	4·05	12·17

TABLE 5

ANALYSIS OF WHEAT PRODUCTION COSTS AT OLDEANI, 1941–2 CROP

Item	Total cost	Cost per acre	Percentage of total cost	Cost per bag
	Sh. cts.	*Sh. cts.*	*Per cent*	*Sh. cts.*
1. Clearing new land (1,380 acres at Sh. 9/49 per acre)	13,094 35	5 43	5·7	1 17
2. Ploughing, harrowing, planting seed, transport of seed to field, etc.	61,379 32	25 45	26·7	5 51
3. Reaping, harvesting and threshing	17,118 76	7 09	7·4	1 53
4. Gunny bags, twine, etc.	12,679 47	5 25	5·5	1 14
5. Game control expenses	499 85	21	0·2	04
6. Depreciation on stores, sheds	4,887 98	2 03	2·1	44
7. Depreciation of wheat machinery at 33⅓ per cent ..	27,187 96	11 27	11·8	2 44
8. Spares and upkeep of machinery	3,035 94	1 26	1·3	27
Total Direct Production Costs	139,883 63	57 99	60·7	12 54
9. General Overheads—				
(*a*) Management and staff salaries	23,389 06	9 70	10·2	2 09
(*b*) Transport allowances	4,055 26	1 68	1·8	36
(*c*) Office salaries, etc.	14,024 00	5 82	6·1	1 26
Total Overheads	41,468 32	17 20	18·1	3 71
10. Transport, clearing and forwarding charges ..	48,666 87	20 18	21·1	4 37
TOTAL COST OF PRODUCTION .. *Sh.*	230,018 82	95 37	99·9	20 62

Costing

In considering the costs set out below it should be kept in mind that the 2,412 acres of wheat were planted in a number of blocks scattered over an area of 150 square miles. None of the blocks was on level land and all were very irregular in shape. Moreover, 1,400 acres were new, undeveloped land. The total yield was 11,155 bags of 200 lb.

The overall cost per acre at first sight appears high. The chief reason for this is the distance the farms are from railhead. Transport costs account for 21 per cent of the total production costs. Another reason is the administration of the farms as a part of a large group of estates under the control of the Custodian of Enemy Property. As a result of this the wheat areas carried one-third of the management and Oldeani office costs (two-thirds being debited to the coffee areas) which was rather high. Certain factors in the organization of the management of the block of enemy estates in 1942 made it impossible to allocate the exact overheads chargeable to wheat. Agricultural machinery has been depreciated at a rather higher figure than is usual. Moreover the cost of clearing the new land, over half the total area, has been entirely written off on the 1942 crop. In spite of these adverse factors, a profit of approximately 25 per cent was made on the wheat crop.

Acknowledgment

I have to thank Mr. Redfearn for having made available all his very detailed field and office records, which made it possible to write this review of the work done at Oldeani in 1942. His suggestions for, and criticisms of, the draft are also gratefully asknowledged.

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NATIVE PADDY CULTIVATION AND YIELDS IN ZANZIBAR

By F. B. Wilson and G. E. Tidbury, Agricultural Officers, Zanzibar

Rice forms the staple diet of the quarter of a million people of Zanzibar. The development of the export cash crops (cloves and coco-nuts) during the past half century and the cheapness of imported rice led to local rice-growing largely falling into abeyance in the pre-war years. It was carried on mainly by women and old men and, in a year of heavy clove harvest, the area under cultivation shrank to very small proportions. Imports of rice came principally from Burma and amounted to approximately 16,000 tons per annum. It was, therefore, a matter of no little embarrassment to Government and population alike when, early in 1942, Burma fell into enemy hands and the prospects of rice importation diminished accordingly.

A concerted drive by officers of the Administration and the Department of Agriculture for the increased planting of food crops was commenced at the beginning of 1942. It was, however, too late to have any great influence upon the 1942 paddy crop, for the preliminary cultivations should have been started in the previous November or December; even so, it was estimated that the area planted to paddy in Zanzibar Island amounted to some 2,500 acres.

By the later months of that year, however, the food planting campaign, supported by legislation under local Defence Regulations, had become so well organized and comprehensive in its application that, by March 1943, well over 10,000 acres of paddy had been established in Zanzibar Island and a similar area in Pemba.

The rice-growing campaign afforded the field officers concerned an excellent opportunity to study native methods under varying conditions. At harvest time many samples of paddy from native plots in all areas were weighed and accurate information was obtain on matters about which it had only been possible to conjecture in the past. The following article records these observations from Zanzibar Island for the season of 1942-43. As the description of paddy growing is, of necessity, in general terms whilst the observations on yield and varieties are more specific, this article has been divided into two separate parts. It is felt that it would not be correct to draw deductions of general application from figures which refer only to a single season.

I—Paddy Cultivation in Zanzibar

In Zanzibar, paddy is grown as a dry-land crop and is never irrigated. This form of rice cultivation is made possible by the heavy and protracted long rains (*masika*) which occur with the south-west monsoon during March, April and May. The average precipitation in the principal rice-growing areas for this period is, approximately, 40 inches. In normal years this rainfall is fairly well distributed over the three months.

The sites upon which paddy is cultivated vary considerably. The principal areas are low-lying flat plains where waterlogging during part of the year has precluded the planting of coco-nuts or other tree crops. The commoner grasses on the plains are *Rottboellia exaltata, Hyparrhenia rufa*, and *Paspalum* spp., whilst certain areas are also characterized by occasional Borassus palms (*Borassus flabellifera*) and mango trees. The soils vary from stiff mottled clays to light sands and the subsoil is usually a retentive clay. The former soils are much richer in organic matter than the sands, which are of poor quality. These plains are exposed to the hot drying winds of the north-east monsoon from January to March and the condition of rice seedlings during this period is sometimes precarious. The other paddy-growing sites are the flat and sometimes extensive basins of small streams and narrow valley bottoms. These show a similar range of soil types but also include rich alluvial soils generally indicated by the presence of dense stands of the giant Aroid (*Typhonodorum lindleyanum*).

The peculiar conditions of Zanzibar have resulted in the evolution of a local technique which centres round the establishment of rice seedlings several weeks before the onset of the heavy rains. As much of the land is owned by Arabs or Indians the native grower must first obtain permission to cultivate a plot of paddy. This is usually granted on a promise to pay rent in kind at harvest time. The size of a plot is usually expressed as the amount of land which a certain quantity of seed will sow. Thus, half an acre of paddy land is normally reckoned as the area on which 4 *pishi*, i.e. about 16 lb., of seed is sown.

Preparation of the land commences in November at the close of the short rains (*vuli*) preceding the north-east monsoon. The first operation is to lay the vegetation by scraping with a large hoe. This is known as *kuvunja mwitu.* The cut sward rapidly dries up and forms a useful mulch which keeps the soil reasonably moist for the next operation of a deep hoeing (*kuchimbua*), which leaves the land in clods. The vegetation which remains unrotted in December or early January is burnt during the course of the third operation, that is, *kuburuga* or the breaking up of the clods into a fine tilth forming a suitable seed-bed. This is usually done by women with a short-handled weeding-hoe. This tedious operation is sometimes greatly assisted by a few light showers of rain.

In the drier areas, which predominate, the seed is sown in shallow depressions made by the heel or a hoe often after a shower in late December or early January, or even in dry soil in the expectation of rain. The seed is covered by dragging branches over the seed-bed. In the moisture areas, for instance, the small valleys where there are streams, the more usual method of sowing is to broadcast the seed on the damp surface. Pre-germinated seed is sometimes used in this latter method.

Whatever the method, the whole of the prepared area is usually sown at once. It is only very seldom that one observes the use of a nursery to provide seedlings for general transplanting. But the planted area will require thinning, and the resultant thinnings are extensively used later for enlarging the plot.

The showery weather at seed time is usually followed by several weeks of hot sunshine and drying north-east winds. The expert cultivator endeavours to get his paddy established with slender shoots of four to six inches long by the time this unfavourable weather sets in. During the dry period the cultivator is extending his plot to accommodate the transplants which will become available soon after the long rains commence in March, but in the absence of sufficient of these seed may be sown a second, or even a third time. Thus a patchwork plot is usually built up and as sometimes several varieties are planted, an extended period of harvest results.

With the onset of the long rains the paddy crop, often looking very dry and yellow, springs to life and commences rapid growth and tillering. Weeds also start to grow and this period is one of the most critical for the cultivator. A battle against weed competition ensues before the rain becomes so heavy that weeding and cultivation become virtually impossible in most areas. By far the most troublesome weeds at this stage are *Cyperus rotundus* and *C. distans.*

Thinning, weeding, transplanting and cultivation continue through March and April. All the work is done with a short-handled hoe. By the time the really heavy rains preclude further work the cultivator who has the situation in hand will have his paddy twelve to fifteen inches high, tillering strongly, and by the nature of its growth preventing further weed competition. Field observations this year confirm that cultivators who were most successful were those who commenced preparatory cultivations not later than the previous November.

Birdscaring commences as soon as the crop begins to come into ear as the newly formed "milky" grains are particularly susceptible to heavy damage by flocks of small birds. Children and women are to a great extent employed in this time-taking occupation. Stones, shouts, rattling tins, and fluttering bits of cloth are the methods commonly used, the early morning and evening being the times when the birds usually feed. The open plains, with practically no cover for birds, suffer very little in this respect, but some of the small valleys in the plantation areas are subject to constant and unremitting attention by numerous small birds.

In 1943 harvest commenced in the most forward areas at the end of May. By the first week in June it was in full swing in the central and southern areas. In the north, however, harvest did not commence in late-planted crops until mid-July. Observations for this season indicate that early-planted crops tillered far better and were less subject to the diseases which appeared towards the end of the long rains. Much labour was wasted by the long-drawn-out harvesting on many individual plots as a result of several different plantings and the frequent use of different varieties of seed.

There are two systems of harvesting. Either the individual panicles are cut off at the neck as they ripen or, less commonly, the straw is cut at ground level and the crop laid in bundles for a few days to dry. Under either system the grain is eventually threshed by beating with sticks. The straw left after threshing is usually burnt or left to rot in large piles.

The figures of crop yield which follow in Part II indicate that there is a pronounced variation in yield between different areas. Unfortunately, the poorer areas are generally the more accessible and many cultivators content

themselves with the meagre yields associated with the sandy soils which are by far the easiest to cultivate. The best paddy cultivators select their plot in one of the more favourable areas and move there for the season. This results in efficient cultivation and heavier crops.

During the development of the crop the only fungal disease which assumed any importance this season was caused by a *Helminthosporium* sp. which appears to have a number of alternative host plants amongst the local grasses. The incidence of this disease was observed to be greater on the late-planted crop and, it was more widespread on the poorer soil types. Insect damage was negligible, the only pests observed being a stalk-borer (*Sesamia calamistri*) and an unidentified beetle which attacked the leaves of the crop in its early stages.

After the harvest the stubble is abandoned to weed growth until next season. Under this system the useful life of a paddy plot is limited and the cultivator is bound to shift after three to five years. In the district of Muyuni, however, the paddy area is strictly limited whilst the local population is large. Here a most useful pulse rotation has been evolved whereby the stubbles are regularly planted to cowpeas and gram. It is considered that the introduction of this leguminous rotational crop has been largely responsible for the maintenance of satisfactory paddy yields in this area under almost continuous cropping.

The varieties of paddy cultivated are principally of the swamp or intermediate types. "Hill" types are grown in Pemba but not in Zanzibar Island. No doubt there are many synonyms amongst the hundreds of native names although it was obvious at harvest that there were a great many different varieties under cultivation. At present hulling is all done by native methods with a pestle and mortar.

II—Survey of the Yields of Paddy for Season 1943

The 1943 survey of the paddy yields of Zanzibar Island consisted in recording over 5,000 random yard-square samples of the rice crop. The work was preceded by propaganda so that cultivators in each district were informed of the day on which the field recorders were to visit their areas and were instructed to be present in their fields. The following table shows the manner in which the rice areas of Zanzibar were divided so that the numbers of samples taken were roughly proportional to their relative size. An accurate estimate of the planted acreage had previously been obtained by the measurement of over 12,000 individual cultivators' plots earlier in the season.

Table I

Area	Approx. acreage of rice	Soil type	No. of samples taken
Cheju	2,000	Stiff clay ..	901
Uzini	500	Rich loam ..	167
Koani	250	Loams (River valleys) ..	103
Muyuni	300	Heavy loam ..	207
Mwera valley ..	250	Heavy loam ..	100
North Magharib and Mangapwani	400	Light sand ..	358
Mahonda	2,000	Sandy loam ..	1,345
Mto wa Maji and Mkokotoni ..	500	Light sand planted with coco-nuts ..	507
Chaani, East ..	1,500	Heavy loam over clay	666
Chaani, Central ..	1,500	Sandy loam over clay	728
Chaani, West ..	1,000	Sandy loam ..	313
Bandamaji ..	250	Sandy loam ..	178
Total ..	10,450	Total ..	5,573

The apparatus used by the recorders consisted of wooden frames of one yard square internal measurements, a small spring balance and a light basket. Samples were weighed to the nearest ounce and varied between one and twenty ounces. The method of sampling consisted in placing the frame at random in the field, all the rice plant inside being harvested and the grain rubbed out and weighed on the spot. The grain was then returned to the owner and a note made of the variety and any other features of interest.

It was realized that freshly harvested grain, roughly cleaned in the field, would weigh less after thorough drying and careful winnowing. To obtain a figure for this shrinkage some 148 samples were taken in the normal manner and then dried, cleaned and re-weighed. It was found that the average loss was 3.4 per cent and all results were reduced by this amount before analysis.

It was found that one recorder, assisted by a labourer, could take about sixty samples per day. The recorders moved about the Island as the crop ripened until all areas were completed.

The results were summarized as distribution curves and the mean yield and its standard error assessed for each rice-growing area. The figures were also classified under varieties for which similar average yields were assessed for each area.

Yields

Table II gives the mean rice yields in terms of paddy per acre for the districts visited.

TABLE II

District	Mean yield (Lb. per acre of paddy)	Standard error
Cheju..	1,781	24·82
Uzini	2,064	52·53
Koani	1,706	78·67
Muyuni	1,641	39·99
Mwera Valley	1,752	79·90
North Magharib and Mangapwani	1,396	34·36
Mahonda	1,489	20·17
Mto wa Maji and Mkokotoni	896	19·27
Chaani, East	1,799	26·09
Chaani, Central	1,404	21·59
Chaani, West	1,140	31·32
Bandamaji ..	1,021	34·98
Whole Island	1,499	9·69

Varieties

Some 148 varieties were encountered, of which many are probably synonymous. Of the total number of varieties 115 were met with on less than ten occasions and 21 were noted less than fifty times, so that figures obtained for their mean yields are not considered to be based on large enough frequencies to be acceptable. The remaining twelve are listed below as Table III.

TABLE III

Variety	Frequency	Approx. mean yield (Lb. per acre of paddy)
Moshi	1,565	1,570
Kibawa	989	1,540
Sokotera	537	1,320
Afaa ..	298	1,500
Kidume	216	1,520
Meli ..	194	1,210
Meza ..	176	1,300
Makaniki	126	1,190
Gamti	119	1,390
Vuli (Shungi) la mbeya	118	1,660
Bungala	57	1,250
Tawazausali	56	1,320

Even amongst these few it is possible that there are synonymous varieties; for instance, varieties Moshi, Kidume, Makaniki and Tawazausali are all dark-coloured rices and strongly resemble one another.

From the records it is also possible to observe that certain rices are more suited to certain districts than others but in most cases the numbers of each variety for individual areas were not large enough to permit of accurate comparisons.

The Size of the Sample and the Accuracy of the Estimate

When the sizes of the samples taken in each district were compared with the resulting standard errors expressed as percentages of their mean weights by means of a graph, it was clear that the relationship is logarithmic and the familiar curve of the uniformity trial was obtained.

The small irregularities in the curve were corrected by plotting the logarithms of both standard error percentages and sample sizes. This gave approximately a straight line as the regression between the two sets of logarithms is known to be linear. By working out a regression coefficient and equation the line was straightened, the corrected points being expressed as anti-logarithms and the original curve obtained more correctly drawn. The percentages were then converted into figures for standard error assuming the mean yield to be that found for the whole Island, i.e. 1,500 lb. per acre.

From this curve it is possible to read off the expected standard error for any given size of sample so long as the average yield of the area sampled is in the neighbourhood of 1,500 lb. per acre.

Thus from the curve may be assessed the size of sample needed for any required degree of accuracy in estimation. The "table of x" as given by Fisher indicates the probability of a mean falling outside any given deviation from the true mean if the value of this deviation divided by the standard error is known.

From this Table IV has been prepared, giving the likely degrees of accuracy required and the sizes of the samples needed to approximate to them.

TABLE IV

Number of lb. within which estimate may differ from true mean	Number of quadrats per sample needed when		
	$P=0·1$	$P=0·05$	$P=0·01$
Lb.			
50	460	650	1,160
100	110	160	260
150	50	70	110
200	*30	*40	*65

*Approx.

These figures are, of course, only approximate and based on an average yield of 1,500 lb. per acre. If a much larger yield is expected

the standard error may be expected also to be larger and therefore a larger sample must be taken and vice versa. The actual size may easily be calculated in the same manner for the expected yield instead of for 1,500 lb. per acre as was done here.

Summary

(1) Native cultivation of paddy in Zanzibar Island is described.

(2) A simple method is described by which the 1943 harvest was surveyed and measured and from which an estimate of total production was obtained.

(3) The mean yield of native paddy grown in Zanzibar in 1943 was approximately 1,500 lb. per acre.

(4) Statistical information is given regarding the sizes of samples necessary to give results of varying degrees of accuracy.

(*Received for publication on 2nd November*, 1943)

CORRESPONDENCE ON CLOVER

Plateau, Kenya,
21st December, 1943.

The Editor, East African Agricultural Journal

Dear Sir,

I would like to see an article on *Sweet and Hubam Clover*. I have seen the statement—in the *East African Agricultural Journal*, I think—that clovers are not successful in East Africa. This is definitely not true, at least in the Kenya Highlands. Hubam clover grows six feet high in my garden, and I am trying to get enough seed for field planting. It appears to me that our Agricultural Departments are missing a trick, in not doing something with this very excellent legume. There must be at least five million acres of sweet clover in the United States alone, where it is grown for pasturage, hay, silage, and as a green manure crop.

I am,
Yours faithfully,
W. L. JACKSON.

Veterinary Research Laboratory,
P.O. Kabete,
23rd November, 1943.

The Editor, East African Agricultural Journal

Dear Sir,

We have made fairly extensive trials with clover (*Melilotus alba*) since 1931. Favourable reports on the Hubam variety were received from the Agricultural Stations at Njoro and Kitale, from the former centre until 1936. An article was published by the late Mr. Ball, Agricultural Officer, Njoro, in the *Kenya Weekly News* of February the 22nd, 1935, setting forth the advantages of Hubam Clover as a fodder crop.

Njoro reports that Hubam Clover has proved its value as a drought resistant crop, while Kitale, which has high rainfall (40-50 inches), reports that it is not of much value as a fodder crop because of the extremely short period between the time that it attains optimum bulk for cutting and the time that it becomes woody and unpalatable to stock.

In my own work the interest has been mainly in the possibilities of *M. alba* as a pasture legume. The preliminary results were sufficiently good at Kabete to merit trial in mixture with grasses. For this purpose, however, the plant proved a failure. In mixture with Rhodes grass it died out within a year.

The crop has not been taken up by farmers in either the Njoro or Kitale districts. The fact remains that in the drier districts of Kenya clovers do not succeed, and in areas at high elevations no pasture legume has yet been found as successful as the indigenous *Trifolium johnstonii*. The points which appear to be of importance are whether *M. alba* would be an improvement upon lucerne as a fodder crop in the areas in which the latter succeeds and whether it can be grown outside the lucerne areas. Our information is not sufficiently complete to answer these questions, although Mr. Ball in the above-mentioned article suggested that the range of the crop is greater than that of lucerne.

Experiments on indigenous and exotic legumes in mixture with grasses have been mainly a record of failures, and so little has yet been attempted in ley establishment in ordinary farming practice, that the information available on pasture legumes in Kenya is quite insufficient to provide material for an article on the subject.

Yours faithfully,
D. C. EDWARDS.

WANYAKYUSA AGRICULTURE

By D. H. Thwaites, Agricultural Assistant, Tanganyika Territory

The Wanyakyusa occupy the District of Rungwe in the Southern Highlands Province. The district lies between 9° and 9½° S. latitude at the northern tip of Lake Nyasa. The altitude ranges from 1,500 feet to 9,500 feet. The district is divided into twelve chiefdoms. The Administrative Headquarters are at Tukuyu, which was known before the British occupation as Neu Langenberg.

Inhabitants

The local people are not indigeneous to this area. They came, tradition has it, from Mahenge via Ukinga after many tribal fights. They are akin to the Wahenga in Nyasaland bordering on the Tanganyika boundary. It is estimated that only 10 per cent of the Wanyakyusa speak Kiswahili. According to the 1935 census the total poulation was 153,204. The total number of tax-payers in 1942 was 35,304, or 23.04 per cent of the total population.

The people themselves are extremely industrious and intelligent. As there are 90 people to the square mile, living conditions are crowded and emigration is continually taking place. The people are partial to litigation over cattle and women. The number of cases heard annually in the Native Courts is about 6,000. There is no one historical and traditional head of the tribe. The twelve Chiefs are, in reality, hereditary Headmen who have been selected by Government to be Chiefs. They are in effect only *primi inter pares* in native eyes, the outlook of the people being unusually democratic for a native tribe.

The people live in houses made of wattle and daub or bamboo frame, with thatched roof, and villages are sited mostly along ridges. Rectangular houses are now built instead of the round huts of former days. They often stand in rows with a main street down the middle with bananas in the background. The more progressive natives build with sun-dried or burnt brick. Stock are stalled in the same house owing to the prevalence of thieving, but sleep in separate rooms.

Climate

The rainfall of the district varies in the different areas. In Tukuyu itself the annual average for 25 years (1918-1942) is 100.22 inches. On the Lake shore the average is probably higher, but no continuous statistics are available. The heaviest rainfall months are from December to May, but, in most years, some rain falls every month in the part north of Tukuyu. Very heavy rains occur at times, such as in 1935 when 139 inches are recorded on the lake shore in the month of April. In November, 1942, 12½ inches fell in eighteen hours in Tukuyu. The average mean temperature for Tukuyu is 23.66°C. The range is low while monthly variation average is only 5-6°C.

Soils and Vegetation

The district may be divided into three sections according to soil and vegetation types. The higher altitudes to the north are dominated geologically by the extinct volcanic range extending round Rungwe Mountain. The dark soil, composed of decaying vegetable matter overlying volcanic ash in varying layers, is, generally speaking, fairly fertile, depending on the age of the subsoil. The vegetation is dominated by rain forest, though much of this has been destroyed. Grass (*Hyparrhenia* spp. *Digitaria horizontalis, Setaria*) and *Crotalaria* spp., with high *Sesbania* and *Dodonea* shrub on the slopes of the mountain range, are found with *Milletia, Ficus* and *Cissus* spp., and occasional stretches of bamboo on the hill sides and in the river beds and ravines. To the west of Tukuyu, woodlands of *Brachystegia,* associated with *Albizzia* and *Parkia* spp., cover such areas as are not cultivated and where the grasses (*Hyparrhenia* and *Digitaria* spp.) can only be burnt during October owing to the wet climate.

In the medium altitudes south of Tukuyu, the soil is a red clay loam, derived from granite with intrusions of dolorite, diorite, basalt and quartz. It is in the area of these soils that hot springs, lime, coal and mica occur. This part is heavily wooded with *Brachystegia* associated with *Albizzia, Dalbergia, Ficus, Cissus* spp. and *Chlorophora excelsa,* but is at present being gradually cut out to make room for cultivation. No forests of economic value occur, except for fuel, small quantities of wild rubber vine, *Landolphia* spp., which have become of value in wartime, and some pockets of *Adina microcephala.* Dominant grasses are *Imperata cylindrica, Digitaria,* and *Hyparrhenia* spp.

The lower altitudes below 2,000 feet are situated in a wide plain along the northern and western shores of Lake Nyasa, and this is composed of soils mostly transported from the highlands. These are extremely fertile. The subsoil is granite and the top soil varies greatly

in thickness. This part is devoid of timber except along some river banks—*Albizzia* and *Acacia* spp.—and fuel has to be carried some distance. The dominant herbs are *Crotalaria striata* and *Hyparrhenia* sp., with *Phragmites* and *Pennisetum purpureum* along the rivers.

Methods of Cultivation

The work of cultivation is equally divided between the sexes. After the plots have been cleared and hand-hoed by the men, it is women's work to plant, clear, harvest, winnow and sell at the market. Men's work consists of clearing, hoeing and looking after the cattle.

Rotation of crops is practised, as it must be in an area where all land is far from productive. In the highlands, 9,500 feet to 5,000 feet, the rotation in valleys is sweet potatoes, finger millet, groundnuts, finger millet, groundnuts, finger millet and rest for five years, or sweet potatoes, maize for five years and rest for five years. On the hillsides, finger millet and pigeon pea or finger millet alone are sown every fourth year.

In the medium altitudes, between 5,000 feet and 2-3,000 feet, the rotation is finger millet, maize and yams, beans, rested and grazed. Continual planting of rice cannot take place as fertility is so quickly impaired.

In the lower altitudes, below 2,000 feet, rice is planted continuously for some 15 years and the land is then rested and grazed for about 8 years.

Diet and Food Crops

No one food is the staple throughout the district, but plantains, maize and sweet potatoes for the higher altitudes and rice on the lake shore are generally eaten, with additions that vary from area to area.

Maize is planted both on contoured ridges and on flat land. Holes are drilled generally 3 feet apart and each hole has 3 seeds planted in it. Maize is usually interplanted with beans or Bambarra groundnuts, groundnuts, cowpeas or pigeon peas. Planting takes place in the highlands in July to September and harvesting in February to April. In the medium altitudes, two crops are planted annually, in November to February and again in May to June. In the lower altitudes, however, little maize is grown and this is sown in November to December and harvested in March and April. Maize is stored in mud-covered basket granaries or is sold as soon as it is dried. It is eaten roasted or boiled with beans. The varieties of maize grown vary but they are mostly of the hard flint type.

Bananas and plantains are grown all over the district except in the highlands to the north and west. Numerous local varieties abound, with a red plantain and the *Sukari* variety of banana as recent introductions, and are used exclusively for food, no beer being made. They are mostly dried and pounded with pestle and mortar to be used as flour, although they are also eaten whole after roasting.

Sweet potatoes are extensively grown. They are planted on contoured ridges from 3-4 feet high. Planting distances vary from 6 inches to 1 foot in either direction. They are planted in March to May and north of Tukuyu take eight months to mature, but south of that place four months is sufficient. Sweet potatoes are eaten boiled or roasted.

Finger millet is used more for beer-making than for food. It is always sown broadcast in November to January and harvested in March to May. The land is first hand-hoed and all grass put into heaps and burnt when dry. In the highlands to the west the trees are lopped and branches piled in heaps to be burnt. Contoured ridges are put in at intervals depending on the slope of the land. The harvesting is carried out just before the grain is ripe by cutting off the heads and stacking in the field while ripening proceeds. The heads are then collected into large baskets and steeped in water for a day, after which they are taken out and rubbed with the hands to separate the grain from the chaff. The millet is then dried and stored in earthenware pots or mud-covered baskets until required. It is reported that it can be stored for five or six years by this method, but I have not verified this personally.

Beans are nearly always interplanted with maize or sown in banana plantations and the local seed is of mixed varieties. They are eaten boiled as a relish with other food such as maize. The leaves are also eaten dried or fresh.

Groundnuts are grown in the medium and lower altitudes. Planted in November to February and harvested in April to July, they are dried in the shell and eaten raw.

Rice is grown on the lake shore and also in the neighbouring foothills. It is sown broadcast in November to February and harvested in May to August. Yields are not high in the foothills, being about 6-7 bags of paddy to the acre. Many local varieties are grown, such as Musafiri, Mwangulu, and Marula. The hill rice is eaten boiled, but most is sold hand-hulled in the markets for purely local consumption.

Other foodstuffs grown are coca-yams, cow peas, pigeon peas, Bambarra groundnuts, ginger, cardamon, groundnuts, wheat, pumpkins, peppers, citrus, sugar cane and European vegetables, including a quantity of European potatoes.

Economic Crops

One of the main cash crops is coffee, which was introduced about 1900 by the Berlin Lutheran Mission, but it was not grown by natives until 1930 when an attempt was made to organize an industry. It had already been tried from 1924 onwards by Europeans but had gradually died out, giving place to tea.

Native coffee has not been truly successful and many reasons are suspected for this. In effect, the coffee suffers from many pests and diseases and yields are so low as to be almost uneconomical even to a tribe of very low individual annual income. It has become obvious that coffee can only be grown by natives if shaded by bananas and mulched heavily with banana trash. Multiple-stem pruning is gaining favour.

Seedlings are planted out in December and the first crop is obtained four years after. The area planted rose in 1939 to 5,864 acres and the number of native planters to 7,966. Yields, however, are low, varying from 131.4 kg. to 20.4 kg. parchment to the acre. Hemeleia leaf disease and yellow and white borer are prevalent all over the coffee-growing area. Over the period since 1932 the price paid to natives has averaged 44 cents a kg. for parchment.

All coffee is collected and sold by Native Authority after rough grading and, in order to encourage better preparation, much lower payments are made for the inferior grades. A native staff is employed to visit coffee plots and to give instructions, and it is noticeable that the quality of preparation varies with the price.

The cultivation of rice on the lake shore was started by Chief Koroso in 1896 with seed obtained from Arab traders in Nyasaland and the Moravian Mission issued further seed in 1898. Being an innovation, rice was not popular and little was grown except for small local sales. In 1917 the Government issued seed and tax was paid in rice instead of money. Interest was hereby aroused and the cultivation of rice was started. In 1932 several other kinds of seed were issued and now sixteen varieties are found. "Faya", which was issued in 1929, gives the best yields and is the variety chiefly grown, other varieties being Bungala, Marula and Mapiko, although very little of these is sold. Ploughs have been introduced into the area as it is flat and the total number in use in 1942 is about 400. The first ploughing is carried out in June or July when the ground is still wet, and the second ploughing in October to February. Planting, which is all broadcast, is carried out in November to the middle of March and the harvesting is done in May to September.

A first mill was erected at Ipyana on the lake shore in 1942 with a capacity of 9 tons of rice in 15 hours. Another is now on its way from India with a capacity of 14 tons of rice in 15 hours and should be erected some time in 1944.

A small acreage of cotton is also sown along the Songwe River boundary, which borders on Nyasaland, with seed obtained from that Colony. Conditions, however, are not suitable on the remainder of the lake shore and expansion is not encouraged.

A list of exports from the district with approximate weights for 1942 is appended:—

Article	Weight in tons
	Tons
Mixed beans	550
Coffee	50
Groundnuts	50
Maize..	1,500
Onions	20
European potatoes	200
Rice	1,500
Vegetables	40
Fruit	100
Banana flour	300
Cassava flour	50
Finger millet	150
Tea (European produce)	215
Total ..	4,725

Land Tenure and Economics of the People

In theory all land belongs to the chiefs or sub-chiefs, but in practice once a man has cultivated a plot, that plot belongs to him until he leaves the area in which he lives. If he leaves, the land reverts to the chief or sub-chief and may be given by him through his headman or elder to anyone in his area who is short of land or to a newcomer who wants a plot. Should a man go away and return after a long period and ask for a plot, he is bound to be given one but not necessarily the plot he had before he left. Newcomers are welcomed and are given land, as the amount of tax collected in an area is an indication of the importance of a chief.

Stock grazing is a problem which is coming more and more to the fore. The number of

cattle in the district in the 1941 census was about 2.3 head per taxpayer or 55 head per square mile. Certain land is set aside each year for grazing, where stock is not able to interfere with the produce plots. Compensation for trespass of cattle on cultivated land is only paid among people of the lake shore.

Parts of the land to the west of Tukuyu have been badly eroded by cultivation and over-grazing, and it is only since 1935 that anti-erosion rules have been made to check the tendency for bad cultivation. Since they were brought in, however, the majority of the tribe have become very keen on seeing the effect that well-controlled cultivation has on crops. The following are the Native Authority Rules concerning anti-erosion:—

"Throughout the Rungwa District, all natives shall follow orders regarding cultivation designed to prevent soil erosion as demonstrated and enjoined by the Agricultural Officer.

(*a*) All ridges and terraces shall be contoured and not follow the slope of the hill.

(*b*) In the case of cultivation done on the flat and not on ridges or terraces, a large ridge and ditch shall be dug at the top of the plot to remain permanently and be repaired from time to time."

The Wanyakyusa have never been dependant on outside sources for any of their food, but in their own territory there is no iron for making hoes nor clay for making earthenware pots. The former they were accustomed to get from Ukinga, on the eastern boundary of the district in the Livingstone mountains, and the pots were, and are still, made only by about 500 members of the Wakisi tribe living in a village on the lake shore at the extreme south-western point of the district. The Wakisi are really of Ukinga origin and inhabit the eastern, northern and western shores of Lake Nyasa. They grow no food except cassava, and that only recently, and apart from the one village that makes the pots, their only work is as paddlers of canoes and fishermen. Most of their fish and pots are exchanged for food.

Since the Tukuyu District is so thickly populated and the inhabitants concentrated, it has been found necessary to create produce markets at comparatively short distances. Transport from these markets, during war-time, has become difficult. The natural outlet for Tukuyu native foodstuffs is the Lupa Goldfields, which lie about 100 miles to the north. Before the war, the goldfields gave work to about 15,000 natives, chiefly Wanyakyusa, and most of the foodstuffs from this district went there. The goldfields are gradually closing due to difficulties in obtaining spares, and it has been necessary to look for outlets for Tukuyu produce elsewhere. Should the goldfields open again after the war, and large-scale mining start, there is a great future for produce grown in Tukuyu.

The main income of the tribe is derived from agricultural, military, mining and public works sources, and it is estimated that in 1941 the average annual income per man, woman and child was about Sh. 10 per year. It has risen considerably since, as over 4,000 men have joined the military and a large part of their salaries comes back to the district in the form of remittances. The agricultural source, from which a larger part of the tribal income accrues, is from sales of rice, maize and other foodstuffs. A fair number of Wanyakyusa also work on the tea plantations.

The picture sketched above will show that the district is inhabited by a tribe whose agriculture is of great interest, since the variety of crops, from wheat in the highlands to paddy and cotton on the lake shore, is perhaps unrivalled in so small an area elsewhere in East Africa. It has not been possible to fill in the picture with details of the people's character, but it is worth mentioning that the Wanyakyusa are a people difficult to administer, argumentative, litigious, self-willed and at times inclined to truculence. Nevertheless their intelligence is such that they are willing to be persuaded, and, once convinced of the benefit of any change, adopt it with energy. This is instanced by the way they have in a few years accepted the principles of anti-erosion to such an extent that now there is perhaps 90 per cent control in the well-populated areas. It should, however, be stressed that, though the soil is not being eroded to any great extent, it is still being impoverished, since increased cultivation for the war effort has involved breaking a great deal of new land with a consequent lessening of fallow. Over-cropping in the hilly country is very great and, in order to prevent further emigration, it behoves the native planters to learn to put something back into the soil in the form of mulch or compost. If care is not taken, a comparatively prosperous country will one day become like so many parts of Africa, where a losing struggle is fought with Nature to obtain a sufficiency for the people's needs.

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NOTES ON ANIMAL DISEASES

XXII—DISEASES CAUSED BY WORMS—(Contd.)

Compiled by the Veterinary Department, Kabete, Kenya

The roundworms have a smooth skin, and an alimentary tract. The sexes are separate and all the larger forms are parasitic. The class is a large one and is divided into five orders, only four of which need be mentioned here. These the the Ascaroidea, Strongyloidea, Filaroidea and Trichinelloidea.

Roundworms of Horses.—There are two members of the Ascaroidea and a large number of strongyles found in equines in East Africa. All of these have a direct life history. Of somewhat less importance are members of the genus *Habronema* (Filaroidea).

Ascaris equorum are large, cylindrical, white or yellowish worms tapering to each end. The males measure up to 10 inches in length and the females up to 15. They are often present in enormous numbers in foals. The best treatment consists in the administration of carbon bisulphide in capsule. Turpentine and linseed oil are also of value. The other important member of the family is *Oxyuris equi*, the pinworm, which lives in the large intestine. These worms are white and cylindrical, the females having a tail very variable in length. The males are about ½-inch long and the females measure up to 6 inches. The available methods of treatment are not wholly satisfactory. The old-fashioned treatment was a strong infusion of quassia chips used as an enema. Oil of chenopodium in a purgative dose of linseed oil is also used.

Of the strongyles there are four members of the genus *Strongylus*, greyish-brown worms, the females of the largest species being a little less than 2 inches in length. The adult worms live in the first part of the large intestine, but during their early stages the worms migrate by way of the abdominal organs and blood vessels. One species, in particular, *S. vulgaris*, is the cause of blockage in the mesenteric arteries, which, if severe, produces a form of colic. Before actually entering the gut the larvæ spend about a month in nodules in its wall.

In addition there are a number of smaller strongyles, members of the genus *Trichonema* and others which are usually known as "red worms". They can be seen moving in the droppings of severely affected animals. The adults live in the large intestine and the larvæ occur in nodules in the wall of the gut.

Three drugs can be used for the treatment of strongyles in horses, carbon tetrachloride, oil of chenopodium and the recently introduced phenothiazine. Phenothiazine when obtainable gives excellent results. It would appear from reports in the literature that this drug is occasionally toxic to horses, but accidents following its use are undoubtedly rare and are probably associated with idiosyncrasy.

The three species of *Habronema* are found in the adult stage in the stomach where one, *H. megastoma*, produces tumours in the wall. The eggs in the droppings are swallowed by maggots in which they develop. The mature flies are then responsible for transferring the larval worms back to horses. This may happen when the flies settle on an open wound to imbibe moisture or the larvæ may be deposited on the skin around the mouth. The worms are ½"-1" in length and very white in colour; they are not very pathogenic and provided they are not embedded in tumors, treatment with carbon bisulphide or carbon tetrachloride is reasonably efficacious.

Roundworms of Cattle.—In cattle, members of all the orders occur, but in Kenya it is unusual to meet with any species in sufficient quantities to cause disease. A species of *Ascaris* is not infrequently encountered in calves. To the naked eye it resembles that of the horse and treatment with turpentine and linseed oil is usually satisfactory.

Of the strongyles, the wireworm and small trichostrongyles are important parasites of calves in Europe and America; but they do not appear to be of much significance in Kenya. They occur in the fourth stomach and early part of the small intestine and, when present in large numbers, they are responsible for diarrhœa, unthriftiness and anaemia. Wireworm may be controlled by the administration of a 1 per cent solution of copper sulphate, the dose being 300 c.c. Wireworm and some of the small trichostrongyles may also occur in sheep and it is advisable, therefore, not to regard land on which cattle have grazed as clean for sheep. Of the other strongyles of the alimentary tract, hookworm have been reported to cause symptoms in calves in Kenya. The species, *Bunostomum phlebotomum*, appears to be restricted to cattle although it is closely

related to that occurring in sheep. The best treatment is phenothiazine at a dose of 20 g. per 100 lb. bodyweight to a maximum of 80 g. The common nodular worm of cattle is also distinct from that of sheep and buck; but one less common species occurs in sheep, cattle and goats. Nodular worm in cattle does not appear to produce symptoms.

Lungworms produce "husk" or "hoose" in calves and yearlings in England, and although conditions seem to be unsuitable for the development of heavy infestations, one species is sometimes found in small numbers in the lungs of cattle in Kenya.

Three species of Filaroidea are encountered. Of these, one *Thelazia rhodesii* is sometimes found in large numbers in the conjunctival sac of calves and is best controlled by picking out with a pair of forceps. Another is a *Setaria* which lives in the peritoneal cavity. It is a thin, white worm measuring usually 3-4½ inches in length and does not produce symptoms. The microfilaria sometimes encountered in blood slides from cattle are almost certainly the larvæ of this species, and the parasite is probably spread by sandflies or midges. The third species has not been collected in a condition permitting identification; but is one of the *Onchocerca* group. These parasites produce nodules in the connective tissue of the brisket and are only found in the slaughter house. They are more common in cattle in Tanganyika than in Kenya.

Roundworms of Sheep.—The common roundworms of the digestive tract of sheep belong to the orders Ascaroidea, Strongyloidea and Trichinelloidea but those of the second order only are of economic importance. The small species of *Strongyloides* (Ascaroidea) is uncommon and does not produce symptoms. Species of *Trichuris* or "whipworms" (Trichinelloidea) are often found in the caecum or blind gut. They are 2-3 inches long, the greater part of the length consisting of the anterior end which resembles a cotton thread. The short, thicker, posterior portion is more easily seen. The head is attached to the wall of the bowel. These parasites are rarely found in large numbers and appear to do no harm to the host.

The simplest way to discuss the strongyles (Strongyloidea) is to consider them according to the site at which they are found.

In the fourth stomach a number of members of the family Trichostrongylidae or "hair-strongyles" may occur. The commonest species is *Haemonchus contortus*. This worm is from one-half to an inch and a quarter in length and rather less than one-fiftieth of an inch in maximum thickness. Both males and females are reddish in colour but the females are thicker and more opaque than the males, and are spirally striped like a barber's pole. The life-cycle is direct. From eggs which are passed in the fæces small larvæ hatch. These feed, grow and moult twice before they become infective larvæ and are ready to infect a new host. When swallowed they pass to the fourth stomach where they cast the sheath of old cuticle which protects the infective stage from desiccation and grow to maturity. The cycle outside the body takes from 5-8 days and, after being swallowed, 3-4 weeks elapse before the females begin egg-laying. About 200 wireworms are commonly sufficient to produce fairly well-marked symptoms in young animals. They are easily seen in the stomach if present in numbers but the method of collection given in Vol. 9, page 178, should be followed if an accurate picture of the degree of infestation is to be obtained. This parasite is undoubtedly the commonest cause of parasitic gastritis in untreated sheep, but is also the easiest to control.

The remaining trichostrongyles are generally referred to as "small trichostrongyles" and with the exception of *Ostertagia circumcincta*, are usually more numerous in the early part of the small intestine than in the fourth stomach. They are all minute, hair-like forms and their presence will be missed unless the sedimentation techniquie is followed. *Ostertagia circumcincta* was almost certainly imported into Kenya with Romney Marsh sheep. In England it is a very pathogenic species in lambs and weaners.

The important parasites of the small intestines are the small trichostrongyles to which reference has already been made and the hookworm, *Bunostomum trigonocephalum*. The small trichostrongyles, known in South Africa as "bank-rot" worms, are members of several genera, the more important being *Trichostrongylus* and *Cooperia*. The life-cycle is similar to that of the wireworm but its duration, where it has been determined, is a few days less.

The hookworm is a very important species in the moister areas of Kenya, for example Molo and the Aberdares; but does not appear to thrive so well in the drier plains country of the Rift Valley and Laikipia. The worms are half-an-inch to an inch in length, stouter than the other nematodes of sheep and a dirty grey-brown in colour. Whereas small tricho-

strongyles appear to prefer the first few feet of the small intestine, hookworm may be found in any part of the small gut with the exception of the early part.

The hookworm is probably the most pathogenic species found in sheep in Kenya. About 100 worms are sufficient to produce symptoms in weaners and the pathogenicity is largely attributable to the volume of blood which each parasite consumes in 24 hours coupled with the blood lost from hæmorrhage into the bowel at the wounds caused by its bites. If a badly infested gut is opened, the parasites will be found attached in small groups along the bowel wall and covered with brown slime. On removing the worms and washing the gut, its wall will be found speckled with minute hæmorrhages which can often be seen from the outside.

Finally in the large intestine are found the nodular worms. The common species is *Oesophagostomum columbianum*. The worms are slightly smaller than hookworm and can be recognized easily by their bent anterior ends and dead-white colour. Larvæ hatch from eggs passed out in the fæces and after the usual two moults the infective forms develop. These are swallowed by a sheep, lose their sheaths and enter the mucosa of the bowel wall. Here they develop further and within 6-7 days moult again. At this stage they are enclosed in a cyst in the bowel wall where they remain for a further 6 or 7 days. They then return to the lumen of the gut, moult again and are young adults.

The larvæ may be overcome by the resistance of the sheep whilst in the cyst and the dead worm in the cyst, or the cyst itself after the larva has left, may become invaded by bacteria in which case a small abscess is produced. Later the contents of the cyst may become calcified. The weakness of the gut wall caused by extensive damage is believed to be responsible for telescoping of the gut, when sudden death may occur. This condition is known in South Africa as "reksiekte". The lesions in the bowel wall are referred to as "pimply gut".

In general, however, the symptoms of a heavy nodular worm infestation are emaciation, debility and persistent diarrhœa. The smallest number of parasites necessary to cause symptoms is not known.

Nodular-worm larvæ outside the body are very susceptible to frost, a fact which probably explains the frequency of these parasites in Kenya as compared with England.

The medicinal treatment of strongyles in the alimentary tract of sheep must be based on the species of worms present. The following table shows the value of the various anthelminthics against the different species. Below this table the method of use of the drugs is given.

Species of worm	Wire-worm	Small Tricho-strongyles	Hook-worm	Nodular worm
Copper sulphate ..	++	Slight	—	—
Wireworm remedy	++	Slight	—	—
Copper sulphate and nicotine ..	++	Fair	—	—
Carbon tetrachloride	++	Variable	++	—
Tetrachlorethylene emulsion ..	++	Fair	?	Variable
Nodular worm remedy	++	+	—	+
Phenothiazine ..	++	Variable	+	++

Copper sulphate, 1 per cent solution, 50 cc. for lambs, 100 cc. for sheep over a year, given as a drench.

Wireworm Remedy and in peacetime Nodular Worm Remedy are prepared at the Veterinary Laboratory, Kabete, according to the South African formulae. Full instructions are issued with these remedies, and sets of dosing spoons to ensure the correct dose for animals of different ages can be supplied. The spoons for nodular worm remedy differ in size from those used for wireworm remedy.

Copper sulphate and nicotine.—A solution is prepared containing copper sulphate 1 ounce, 40 per cent nicotine sulphate 1 ounce in 3 pints of water.

The dose for lambs is 15-30 cc. according to size and is followed by a dose of castor-oil. It should be given two hours before the sheep are let out in the morning. Treatment may be repeated at 3-weekly intervals.

Carbon tetrachloride.—Two methods can be used. The first consists in administering 1 cc. of the drug for 10 lb. body-weight by *stomach tube* followed immediately by epsom salts. Lambs and weaners should receive 1 ounce of salts in solution and sheep over 12 months 2 ounces. This method is recommended when grazing is dry. In the other method three mixtures of carbon tetrachloride and liquid paraffin or a light-grade motor oil are prepared and given as follows:—

Lambs and weaners, 20–35 lb.

$\left.\begin{array}{l}\text{3 c.c. carbon tetrachloride}\\\text{7 c.c. liquid paraffin or oil}\end{array}\right\}$ Dose 10 c.c.

Weaners, 35–50 lb.—

$\left.\begin{array}{l}\text{4½ c.c. carbon tetrachloride}\\\text{5½ c.c. liquid paraffin or oil}\end{array}\right\}$ Dose 10 c.c.

Adults—

$\left.\begin{array}{l}\text{6 c.c. carbon tetrachloride}\\\text{6 c.c. liquid paraffin or oil}\end{array}\right\}$ Dose 12 c.c.

This treatment can usually be employed with safety when the grass is green. With both treatments the sheep should be penned in the afternoon of the day prior to dosing, dosed early in the morning before being allowed food or water, and then released.

Tetrachlorethylene is usually administered as Ortlepp and Mönnig's emulsion. Sufficient emulsion to dose 600 adult sheep is made as follows:—

1 gallon tetrachlorethylene
1 gallon liquid paraffin
1½ pints croton oil
2/3 gallon water
2 lb. soft soap

Dissolve the soft soap in the water in a vessel that can be shaken vigorously and is large enough to hold the final amount of emulsion.

Mix the tetrachlorethylene, liquid paraffin and croton oil in a separate vessel. Add the oily mixture little by little to the soap solution, keeping the solution well shaken.

Although the croton oil tends to separate slightly, the strong emulsion can be kept. Before use it is well shaken and the required amount is diluted with half its volume of soft water.

The diluted emulsion is given immediately after a dose of 10 cc. of 2 per cent copper sulphate solution made by dissolving 2 lb. of copper sulphate in 10 gallons of water. The dose of the diluted emulsion is as follows:—

Adult sheep over 12 months ..	30 cc.
Lambs over 6 to 12 months ..	22 cc.
Lambs of 3 to 6 months ..	15 cc.

The remedy must be administered slowly into the side of the mouth, and the mixture should be kept well stirred when in use. Animals must be treated when it is cool, the best time being late in the afternoon. Care should be taken not to chase the sheep about before, during and immediately after treatment. It is recommended that two treatments be given at an interval of 14—21 days.

Phenothiazine.—This new drug will be of the greatest value to sheep farmers once supplies are available at reasonable cost. The dose recommended is 0.5 g. per lb. body-weight or 10-15 g. for lambs over two months 20-30 g. for adults. The only difficulty in using this drug is the bulky nature of the dose, but tablets are now produced which can be given as pills.

Roundworms of Pigs.—Although members of all the four important orders of roundworm occur in pigs, the only species of real economic importance in East Africa is *Ascaris lumbricoides.* This species is a large, yellowish-white worm which in the adult stage lives in the small intestine. The eggs which pass out in the fæces are very resistant to desiccation and to the action of disinfectants. After several weeks they mature and if swallowed by a pig, hatch in the stomach or small intestine. The larvæ penetrate the wall of the gut and travel by the bloodstream to the liver and on to the lungs where they grow and moult twice. After the second moult they escape into the air spaces of the lung and migrate up the windpipe to the throat from where they are swallowed back to the stomach and intestines. Here they moult for the last time and become adults. The time from ingestion of the egg to the appearance of larvæ in the trachea varies from 7-23 days.

Young pigs with a heavy infestation of larvæ in the lungs show the symptom known as "thumps", a name sufficiently explanatory to enable anyone who has seen the condition to recognize it. Large numbers of adults in the gut are responsible for marked unthriftiness. The best treatment is undoubtedly oil of chenopodium, 0.46 c.c./10 lb. body-weight up to a maximum of 12 c.c. The dose should be given in castor-oil (1-2 ounces according to the size of the animals) before the pigs are fed in the morning.

When oil of chenopodium is quite unobtainable carbon tetrachloride may be used but this drug is neither as efficacious nor as safe for pigs as oil of chenopodium. The dose is 30 c.c. mixed with 90 c.c. of a light mineral oil for a pig weighing 100 lb. For smaller pigs the dose is reduced in proportion.

Every effort should be made to rear young pigs as free as possible from these worms. Sows should be treated 3-4 weeks before farrowing and a day or two before farrowing they should be well scrubbed with soap and water and placed in a clean sty. When the piglets are ten days old they should be moved to a fresh sty or, if possible, to movable huts on clean pasture.

Roundworms of Dogs.—The important roundworms of dogs are the ascarids of puppies and the hookworm. Filarid worms which live in the heart and produce microfilaria in the blood are common in most of the lower parts of Kenya. A related worm, *Spirocerca,* is occasionally found in tumours in the wall of the gullet and stomach, but is rarely diagnosed during life.

The two closely related ascarids, measuring 3-8 inches in length are yellowish-white in colour and live in the small intestine. They are responsible for unthriftiness and, on occasion, fits in puppies. Oil of chenopodium 1 c.c. per 22 lb. in castor-oil is efficacious.

Ancylostomum caninum is the common hookworm of dogs and is found on rare occasions in human beings. This parasite is related to, but quite distinct from, the hookworms of ruminants. The worms are just under an inch long and live attached to the wall of the small intestine.

Hookworm infestations should be treated with carbon tetrachloride in capsules, the dose being 3 c.c. per 22 lb.

Roundworms of Poultry.—A considerable number of species of roundworms are found in poultry, all the four orders being represented in East African birds. In Kenya the members of the Ascaroidea are by far the most important. They are *Ascaridia galli* found in the

small intestine of fowls and turkeys, and species of the genera *Heterakis* and *Subulura* found in the cæca and rectum. *Ascaridia galli* are fleshy, white worms, the males being 1-3 inches and the females 2 to almost 5 inches in length. The cæcal worms are about ½-inch in length, but easily seen when present in quantity or when the contents of the cæca are washed. The life-cycle is direct and both types may be the cause of wasting and anæmia in poultry. Nicotine sulphate is the usual remedy. One teaspoonful of 7 per cent nicotine tobacco extract is *well mixed* in three pints of mash. Mash so treated is fed for several days in succession and the birds are then moved to clean ground.

Of the Strongyloidea, the gape worm, *Syngamus trachea*, has been recorded from Uganda, and we have heard of its occurrence in Kenya. These blood-sucking worms are red in colour and live in the trachea of poultry. The females are from half to nearly 2 inches in length and the much smaller male remains permanently coupled so that the pair are like a letter "Y", both heads being attached to the mucous membrane. This species may be spread by wild passerine birds and it would appear that earthworms may serve as intermediate hosts although an intermediate host is not essential.

The latest treatment in America is to expose the birds to a dust of barium antimonyl tartrate. The birds are placed in a box with about 6 inches headroom and one-third of the dose of powder is blown in with a dust-gun at five-minute intervals. The box is rocked occasionally to cause the birds to flutter, thus keeping the dust agitated and the birds panting. For a box of 8 cubic feet capacity a total of 1 ounce of the powder should be used. Until recently the best method of treatment was removal with a fine wire bent into a corkscrew spiral.

Of the Filaroidea the commonest representative is *Tropisurus*, the red females of which live in the glands of the proventriculus of all species of domestic poultry. The life-cycle is indirect and they do not appear to be of much importance. Another species is *Gongylonema ingluvicola*, a long, rather robust worm, which is sometimes present in enormous numbers in the crop of fowls. The larvæ develop in insects.

Finally of the Trichinelloidea we have species of *Capillaria*. These are very fine worms and have never been found in numbers in Kenya. In other countries they have been known to cause severe outbreaks of disease in young birds.

Ringed Worms

The only ringed worm parasites of the domesticated animals are the leeches. These animals are found in sluggish rivers, dams and lakes. The skin is built up of rings and there is a sucker at each extremity. Leeches are markedly contractile and progress by "looping". They live on blood, attaching themselves to the bare areas of skin around the lips, nose and eyes and in the nose, mouth and throat of animals when drinking. On the external parts they soon become detached but leeches often remain attached in the mouth, pharynx or nasal passages when they may cause difficulty in breathing and in swallowing. The presence of these parasites may be indicated by blood-stained froth around the mouth or nostrils or by stertorous breathing.

Leeches which can be reached may be removed by gripping them with the hand wrapped in a dry cloth or with a pair of toothed forceps. For those in the nose or pharynx a couple of ounces of a warm solution of salt, vinegar or chloroform may be injected into the nose or back of the throat with a piece of thin rubber tubing attached to a syringe. Leeches in dams may be killed by the addition of copper sulphate to the same concentration as is required to kill snails.

HEALTH AND AGRICULTURE

My thesis is that man needs to live in an environment which is a just balance between that which nature gives him and that which he creates wholly for himself. He needs to do this if he desires to be mentally, spiritually and bodily healthy and sane, and also superbly progressive . . . I hold that a wholly man-made environment can never satisfy man and therefore that the greatest mistake of the past 100 years and more has been the ever sharper segregation of agriculture and the rural from manufacture and the urban. We must guard as much against being all-rural as being all-urban . . . The problem is this—Enough food for everybody everywhere, enough really fresh food for everybody everywhere, and everywhere a balance of interests. . . . We must have world harmony in mind and there can be no world harmony in my opinion until the rewards of agriculture and the amenities of rural areas are brought upon a par with those of industry, and that the world over.

Prof. Sir George Stapledon.

REVIEW

THE EFFICIENCY OF GROUND LIMESTONE ON GRASSLANDS IN NEW ZEALAND.

Messrs. A. G. Elliott, P. B. Lynch and B. W. Doak, have recently completed an extensive investigation* on the top-dressing, with ground limestone, of grasslands in various parts of New Zealand. They included some interesting work on the response of grasslands, that usually required liming, to various grades of ground limestone. Very large numbers of small scale field trials on the "response survey" method were undertaken to find out the comparative effect of the fineness of grinding, the hardness of the material and the optimum frequency of the dressing. The liming trials were included as part of multiple field experiments involving the crossing with lime of four plots receiving respectively, no manure, superphosphate, superphosphate plus potash and potash only. The response to lime was measured as the difference in the response of superphosphate plus lime from that of superphosphate alone, or, where a marked potash deficiency was observed, the different extra response in the potash plots crossed with a top-dressing of ground limestone. This method overcame difficulties arising out of possible deficiencies of phosphate or potash. Trials were laid down for a minimum period of three years and observations of the sward were made four times in each year. The sward responses were recorded in the light of several factors, such as type of original sward, system of farm management, effect of stocking, uniformity of soil and pasture and history of the trial areas. With very large numbers of such trials and the replication of plots, the differences brought about by the above-mentioned factors could be eliminated.

In certain instances replicated mowing trials were made under the "mowing and grazing" technique devised by Mr. A. W. Hudson, former Crop Experimentalist to the New Zealand Department of Agriculture. This special technique was used so that one half of the trial area was under sheep grazing while the other half was being mown and the material weighed and used for analyses. After two weighings were obtained from each plot, they were put under sheep grazing while the production of the duplicate plot was measured. This technique enabled continuous production records by mowing to be secured without resulting in a deteriorated sward as might be expected to result from continuous mowing only.

It is interesting to note that in all cases general agreement was secured between this "mowing and grazing" technique and the previously mentioned "response survey" grazing trials when relative response was based on sward observations only.

These investigations on liming grassland in New Zealand have been very comprehensive and a vast amount of data relative to about 1,400 separate trials throughout New Zealand has been secured. In this note on the work it is only necessary to draw up a summary of certain results obtained from this wide range of liming treatments.

(i) Both chemical analysis of the soil and yield of herbage data showed that a top-dressing of ground limestone containing at least 50 per cent of material passing a 30-mesh sieve was satisfactory. A finer material was rather better for the first year of the trial while the coarser material maintained improvement over a longer period. It was concluded that the cost of further finer grinding was not justified.

(ii) It was concluded that though a soft limestone may react with the soil somewhat more quickly, hard limestone of the same fineness of grinding is just as satisfactory over a number of years. Thus greater softness and finer grinding make for earlier response, whereas harder limestone and coarser grinding result in a slower but more lasting response.

(iii) Conclusions have been drawn from certain experiments on grassland carried out at the Marton Experimental Area over a period of eight years. These appeared to indicate that an initial dressing of one ton of ground limestone per acre followed by further similar dressings at four-year intervals will maintain the lime-status of the soils in question at a high level and make for maximum pasture production. There was little difference between such dressings and small annual dressings of, say 5 cwt. per acre, except that the former had the advantage of rapidly increasing pasture production within a year or two after the first initial dressing. This conclusion would not necessarily apply to other districts with varying soils and rainfall.

* N.Z.J. Science Technology, Vol. XXIII, Nos. 1A and 2A, pp. 24A, 30A and 57A; June and August. 1941, respectively.

(iv) Other results of these trials are only of interest to the particular districts and soils concerned. Appropriate recommendations are made on the need of liming the more important pasture lands of New Zealand. Out of a total of 1,405 trials scattered throughout the Dominion, it was found that good response was obtained in 381 cases and slight response in another 464, whereas in 560 there was no response to the liming of grasslands.

This extensive investigation will be of great and permanent value to the State and to individual farmers in New Zealand. It has indicated the districts and the soil types in those districts where the liming of grasslands is essential for maximum production. It has also shown that the choice of a particular type of limestone and expensive fine grinding is of little importance and that purchase should be based on the purity or calcium carbonate content of the material and on the amount of transport involved.

There remains the question of whether it is possible to deduce from the above investigations any sound information that is applicable to East Africa. It is not possible to draw conclusions as to the liming requirements under local conditions of climate and soils: these will have to be worked out by field experimentation in the areas concerned. However, certain of the general findings, which are similar to those demonstrated by liming trials in other parts of the world, are likely to be applicable here. It is the old leached soils of hilly districts in areas of high rainfall that are in the most urgent need of liming, whereas younger soils, and more especially alluvial soils, are in less need, or may not require any liming. In dry areas liming is seldom required as it is rainfall and the extent of past leaching that are the main factors in impoverishing the lime-status of most soils. The more fundamental work on the response with varying hardness and fineness of ground limestone will also be more or less applivable to East African conditions. Under local conditions, where transport charges are comparatively heavy, ground limestone should be purchased from the source requiring least rail and, more especially, road haulage, provided that the calcium carbonate content of the material justifies this choice..

As indicated above, we have as yet no sound information on the response to liming of local soil types. Under East African conditions where the price of arable lands and many crops are relatively low as compared with the cost of ground limestone delivered on to the farm and, where there is much undeveloped land, the question of the economy of liming—even though there be a response—is very uncertain. Up to the present very little liming of land has been done by farmers and the few who have carried out such a treatment have generally done so, not because it has been shown that liming increases the yield, but because it was known that liming has long been the approved practice of better farming in the old established farming countries.

It happens that the optimum range of soil reaction values quoted for crops grown in humid soils in temperate climates is not always applicable to local conditions. Lucerne, clovers, the brassicas, beans, and certain cereals are generally supposed to be sensitive to soil acidity and yet we find that all these crops do very well in the leached, quite acid soils of the Kenya Highlands, as long as soil moisture and nutrient conditions are otherwise favourable. The above crops grow well and produce good yields in soils with p.H., values of 5.5 and occasionally in still more acid soils having p.H., values as low as 5.2. Again, in the case of drained swamps, prolific growths of sugar cane and vegetable crops can be produced from peaty soils having p.H., values as low as about 4.5 These examples illustrate the difficulty of interpreting the true significance of such single soil values and show the need for properly carried out liming trials for different soils and crops.

Until such time as the Agricultural Department can offer sound advice on the need of liming different soils, based on field trials, farmers are advised not to lime any extensive areas. In the past there have been a few instances of lime being needlessly applied to large acreages of calcareous soils. It is suggested that farmers do not lime large areas until they have seen the effects of relatively heavy dressings on representative, small half-acre or acre plots scattered on several soil types that may occur on the estate. If there be no response after a couple of years, then they can save on the heavy expense of widespread liming, whereas if crops do better on certain of the limed plots, then they can extend the liming accordingly, giving priority to lands represented by trial plots which have shown the most marked response. Trial dressings could be broadcast at two tons of finely ground limestone per acre and the subsequent extension of liming at about half a ton per acre..

G. H. Gethin Jones.

CORRESPONDENCE

THE FUNDAMENTAL ECONOMICS OF EXPORT CROPS

Mahenge,

24th February, 1944.

The Editor, East African Agricultural Journal

Dear Sir,

The two commentaries by V.L. and E.F.M., which were published in your October issue, deal with a number of points I raised, and also very successfully demolished certain views I did not express and, for that matter, do not hold. For example, who suggested that "we shall have to stop"—"stop", mark you—"growing crops for export"? Certainly not I. Neither did I imply, as V.L. seems to suggest, that we should "ascribe all declining fertility to loss of minerals". On the contrary, I specifically stated that conservative methods, "rotations, mixed farming, anti-soil erosion measures and so on are essential if the best use is to be made of the land", and the only reason I did not deal more fully with such important matters was the quite good one that my article happened to be about something else!

But let us leave that, and turn to V.L.'s and E.F.M.'s remarks on what I *did* say. V.L. tends to belittle the effect of loss of soil minerals by pointing out that "only phosphate and potash are really significant". The word "only" is curious, considering that a deficiency of even one essential element in available form—and both phosphorus and potassium *are* essential—seriously reduces yields, may be to zero if the deficiency is pronounced enough.

V.L. seems to imply that such a catastrophe is most unlikely by quoting the classic Rothamsted experiment, but surely the condition of the Broadbalk Field after 100 years of wheat can scarcely form a reliable guide to that of East African lands after being under, say, maize for a like period.

Nor do I consider the undoubtedly large reserves of plant nutrients under the soil as entirely germane to this part of the argument. It is what is available in the surface layer which counts as a rule, a lack of available nutrients in the all-important top few inches spelling infertility from the farmer's point of view: and I do not have to tell V.L. of all people what is apt to happen under East African weather conditions to soils deficient in plant nutrients in the surface layer, nor to point out the great danger of these soils being very largely destroyed, or even lost altogether, before their fertility can be restored. There is a chemical as well as a mechanical aspect of soil erosion.

True, we *may* be saved by events, as V.L. suggests, but equally well, we may not, and I for one am not prepared to emulate the medieval banker who refused to face impending insolvency in the hope that the timely discovery of the philosopher's stone would end his troubles and replenish his depleted coffers.

E.F.M.'s short comment is interesting. He says my "case is overstated", and then goes on to produce evidence to support it. He approves the policy of maintaining soil fertility by means of grass rotations, having reached the conclusion that in Uganda at any rate "soil fertility is more a matter of physical condition . . . than . . . chemical composition." This statement would, I think, have been framed rather differently by a colloidal chemist, but leaving that aside, and ignoring any chemical action the grass may have in rendering elements available, surely E.F.M. has completely overlooked the very important point that while the land is under grass the loss of available phosphorus and potassium, which V.L. considers "really significant", is greatly reduced, if not arrested altogether. In certain cases there may be, and probably is, a gain. In other words, the grass rotation, besides any mechanical or chemical action it has on the soil, helps to adjust the balance, I considered so important, between the rate at which minerals (and, of course, other nutrients too) are exported from, and replaced in, the surface soil.

I might add that I wrote my article as I did, not to belittle in the slightest the importance of any method of conserving fertility, but because I thought, and still think, certain research work on minerals to be necessary, and because I perceive in some quarters a tendency to forget the Law of the Conservation of Matter to the point of imagining that in farming you can by roundabout methods get something for nothing.

Yours faithfully,

A. T. CULWICK.

Chemical Laboratory,
Dar es Salaam,
29th December, 1943.

The Editor, East African Agricultural Journal

Dear Sir,

Referring to Mr. Culwick's article on the Fundamental Economics for Export Crops in the October issue of the *East African Agricultural Journal*, the following rough calculations may be of interest.

Suppose the draining area of East Africa equals approximately 250 million acres and an average of 20″ of rain falls, of which one-third reaches the sea after passing through the soil, then 167,000,000,000 tons of water annually leach the soil. If this contains the quite moderate amount of 100 parts per million soluble salts, the annual removal of soluble salts from the soils and rocks of East Africa amounts to approximately 17,000,000 tons.

It can be calculated from Clarke that three billion tons of soluble materials are removed annually from the surface of the earth by rivers. Putting the draining surface of the world at 44 million square miles, and calculating the loss from East Africa in proportion to the whole, then 27 million tons of soluble salts would be lost annually. This figure is of the same order of magnitude as the 17,000,000 tons quoted above, and probably indicates that the latter is a conservative one.

Further, on the basis of average content of Ca. in river waters and the average content of Ca. in average igneous rock, 17,000,000 tons of soluble salts is equivalent to the annual dissolution of a thickness of 0.03 mm. of rock over the draining area of East Africa. This amounts to about 1″ in 1,000 years, which is, perhaps, of the same order as the rate of geological peneplanation.

Supposing the average composition of river waters to be:—

SiO_2	..	12.8
Al_2O_3	..	0.9
Fe_2O_3	..	0.4
Ca.	..	14.7
Mg.	..	4.9
Na.	..	9.5
K.	..	4.4
Cl.	..	6.75
SO_4	..	11.6
P.	..	Trace.

then the annual loss from East Africa in rivers of the more important plant nutrients is:—

Calcium: 2,460,000 tons.

Magnesium: 820,000 tons.

Sodium: 1,586,000 tons.

Potassium: 735,000 tons.

Phosphorus: A small amount.

Taking the average composition of igneous rocks as:—

SiO_2	..	59.09
Al_2O_3	..	15.35
Fe_2O_3	..	7,29
Ca.	..	3.60
Mg.	..	2.11
Na.	..	2.97
K.	..	2.57
Cl.	..	0.05
SO_4	..	0.15
P.	..	0.1

and supposing that the annual Ca. loss represents an annual breakdown of an equivalent amount of rock and that other nutrients split off from parent material as rapidly as calcium, then considerable amounts of nutrients are, more or less, liberated annually and are retained in vegetation, sub-soils and bottomlands. These are calculated to be roughly as follows:—

Magnesium: 620,000 tons.

Sodium: 444,000 tons.

Potassium: 1,020,000 tons.

Phosphorus: 68,000 tons.

This amount of potassium could be stored in less than a ton per acre of vegetation over the draining area of East Africa (assuming K. content of vegetation 0.5 per cent). This is not a very large yield of grass or anything else.

The burden of all the above calculations is that the natural wastage of nutrients in rivers and amounts locked up in vegetation, subsoils and bottomlands completely dwarf the amounts lost by export of crops. For example, the loss of Ca. in rivers equals on Culwick's figures, 12 billion tons of paddy rice.

The lack of nutrients in topsoils is, nevertheless, a real problem. Milne has repeatedly urged the study of the utilization of bottomlands which are chemically fertile, but physically infertile.

The right aproach to the problem on upland soils appears to be the tapping of the relatively

enormous though perhaps somewhat unevenly distributed resources of subsoils and bottomlands through vegetation, and if you will, the cow. Organic matter confers favourable properties on soils which make up the sum total called fertility-good structure favourable to root development, proper balance of air and moisture, development of essential bacteria, stability under erosive influences, etc. These things are as essential as plant nutrients.

Organic matter, besides containing plant nutrients is capable of retaining many times more nutrients than inorganic matter and because of this any attempt to raise the nutrition of East African plants to an optimum level by artificial manures would be wasteful, if not impossible, without some organic matter.

On the other hand organic matter is much more oxidisable than inorganic matter and must, therefore, be continually renewed. The problem, in fact, is the complex one of soil management, and East African agriculturists seem in the line to solving it by advocating mixed farming.

I am, Yours faithfully,
W. E. CALTON.

Morogoro,
24th December, 1943.

The Editor, East African Agricultural Journal
Sir,

Mr. Culwick has raised a point worthy of investigation and under conditions of permanent farming his hypothesis may be correct. It is a sound maxim in farming that you cannot get something for nothing from Nature. But I feel that both he and Mr. Liversage have overlooked the fact that far greater losses in plant food are occurring all over the world as a result of accelerated erosion. In 1928 it was estimated that each year the streams of the United States carry into the ocean 126 billion pounds of plant food material which is more than 26 times the plant food used by plants in the same period. A very large portion of this loss is due to accelerated erosion on cultivated lands and pastures. It has also been shown in America that on lands suffering from erosion the soil is washed away twenty times faster than it can be replaced by nature. Mr. Liversage suggests that "Micawberlike we may hope to be saved by events". This does not answer the question raised by Mr. Culwick and will be of no avail whatever against the destructive forces of soil erosion. Surely the answer is that we must first of all stabilize our soils and then ascertain to what extent nature is able to replace the plant foods removed by the crops we grow.

A. H. SAVILE,
Senior Agricultural Officer,
Eastern Province.

Msambweni,
Private Bag, Mombasa,
9th November, 1943.

The Editor, East African Agricultural Journal
Sir,

As one who has an intimate knowledge of the area extending over a period of years I have some criticism to offer on Mr. Culwick's article which appeared in the October issue of the *East African Agricultural Journal.*

I refer to the paragraph dealing with the coffee and banana belt on the western shore of Victoria Nyanza. If Mr. Culwick has written from first-hand knowledge of the area I fear that he has misinterpreted what he has seen; if, on the other hand, he writes from what he has read or been told, then he has been somewhat misinformed.

The area referred to is one of the few places in East Africa where the native has evolved a technique in the cultivation of his staple food that enables him to remain anchored to the same piece of land, as far as one can see, indefinitely; and, barring locusts or prolonged drought, to obtain a steady and adequate supply of his staple food.

In the first place the Bahaya banana plantations are usually sited in areas formerly covered with heavy evergreen primeval forest which can be seen by the huge isolated forest trees which for one reason or another have been left, and occasional patches of the original forest which have been retained as an abode for the ancestral spirits of the community.

The fertility of this soil is maintained by the provision of a permanent mulch of the outer leaf-sheaths of the banana stem which are periodically stripped and laid down with meticulous care so that not a patch of soil remains visible and also the whole stems which are cut up and left to rot each time that

a bunch is used; in addition, all banana peelings and other household vegetable refuse is returned to the plantation, although the latter does not as a rule extend any great distance from the door of the dwelling. The staple protein food is a legume, the Lima bean, and this is grown as an annual undercrop in the banana plantations, the nitrogen-fixing roots of which are left to rot in the soil.

Cattle are comparatively few in this area and plurality of ownership is quite common; the amount of cattle manure available is therefore restricted. The value of coffee as a cash crop together with pressure of population has forced people to extend coffee and banana cultivation into the open grassland outside the original forest areas, and it is here only that grass mulch and crop residues are used.

I agree with all that Mr. Culwick has to say regarding the fertility of the Bahaya grasslands. More than one Agricultural Officer has found this out to his cost when endeavouring to establish those demonstration plots so excellent in theory, but often such a dismal failure when put into practice. I see no reason to believe that the grazing was ever any better than it is now; in my opinion, the dominant grass is a "climax" species in that particular vegetation type.

In practice, however, these grasslands are used only to a limited extent for the cultivation of food crops, and then only for what might be called traditional Bahaya crops such as Bambarra groundnut, yams and a species of Coleus grown for its tuberous roots. Of these the yam is the only one that gives a reasonable return for the labour involved. The yield of Bambarra groundnut in these grasslands is pitifully small when considering the labour involved and the fact that land can be cropped once only in four years, but I see no reason to believe that it has ever been otherwise on this particular type of soil.

I am, Sir,

Yours faithfully,

L. C. EDWARDS.

District Office, Mahenge,
24th December, 1943.

The Editor, East African Agricultural Journal

Sir,

I thank you for forwarding me Mr. Edwards' letter criticizing my statement in your October number regarding the Bukoba banana and coffee belt. I agree that it is possible that I misinterpreted what I saw during my year's investigation there, and that the various departmental officers, who so kindly assisted me, were also at fault in their observations, but, if seeing is believing, I feel fully justified in adhering to my statements.

While granting the utmost importance of laying down banana trash, intercropping with legumes, and so on, there is a large importation of fertility in many different forms from the open lands into even the oldest plantations. To take but one example, Mr. Edwards will doubtless recollect the large amount of grass imported into every settlement for laying down as a thick carpet on the floors of the huts. This is renewed weekly, the discarded grass being thrown out on to the permanently cultivated lands.

I consider it an unwarranted assumption that the present grasslands have always been as they are to-day. Surely, all the evidence points to most of them at any rate having also been under evergreen forest at one time. It is interesting in this connexion to record that I have actually seen one area of ordinary poor Bukoba grassland which had gone back to bush containing large numbers of self-sown *Mysopsis* and *Podocarpus* trees when fire had been rigorously excluded for some years.

A survey carried out by a member of the Agricultural Department in 1938 shows that Mr. Edwards has grossly underestimated the extent to which the grasslands are cropped. Although a given family cultivates but a small area at any one time, it must not be forgotten that only a single crop can be taken off this type of land, after which it must be allowed to remain fallow for anything from three to eight years, or even more. This, coupled with a dense population which runs up to 385 persons to the square mile in Kiamtwara, means that a large proportion of the grassland is cropped to its full capacity, a practice which obviously has its effect on the already poor grazing, particularly when crop residues are removed for mulching bananas or coffee land. In the circumstances, I see nothing improbable in the view I have heard expressed, that the cattle population has fallen from about 400,000 in the middle of the last century to a mere 50,000 head in 1938, partly owing to disease, but also largely as a result of increasing malnutrition and consequent infertility following on the progressive impoverishment of the pastures. (*See* Brett, E.A.A.J. IV, 5, 1939.)

Yours faithfully,

A. T. CULWICK.